# USE OF DROP-NETS FOR WILD PIG

# DAMAGE AND DISEASE ABATEMENT

A Thesis

by

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# ABSTRACT

Numerous trap designs have been used in efforts to capture wild pigs (*Sus scrofa);* however, drop-nets have never been examined as a potential tool for wild pig control. I implemented a 2-year study to compare the effectiveness and efficiency of an 18.3 x 18.3 m drop-net and a traditional corral trap for trapping wild pigs. In spring 2010, treatment units were randomly selected and multiple trap sites were identified on 4,047 ha in Love County, Oklahoma. Trap sites were baited with whole corn and monitored with infrared-triggered cameras during pre-construction and capture periods. Unique pigs using trap sites were identified 5 days prior to trap construction and used in mark-recapture calculations to determine trap effectiveness. Three hundred fifty-six pigs were captured in spring of 2010 and 2011. I documented maximum captures of 27 and 15 pigs with drop-nets and corral traps, respectively. I removed 86 and 49% of the unique pigs from treatment units during the course of the study using drop-nets and corral traps, respectively. Catch per unit effort was 1.9 and 2.3 h/pig for drop-nets and corral traps, respectively. Wild pigs did not appear to exhibit trap shyness around drop-nets, which often facilitated the capture of entire sounders in a single drop. Use of drop-nets also eliminated capture of non-target species. During my study, damage by wild pigs was reduced by 90% across the study area, verifying control reduces damage on native rangelands. Population monitoring for pseudorabies virus, brucellosis, and porcine reproductive and respiratory syndrome resulted in exposure rates of 24, 0.4, and 0.4%, respectively. Removal of wild pigs reduced rooting damage and probability of

encountering pig borne diseases of importance to livestock and human health. My research confirms drop-nets can be an effective tool for removal of wild pigs.

# ACKNOWLEDGEMENTS

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# CHAPTER I

# INTRODUCTION

Wild pigs (*Sus scrofa*) are not native to North America, but have become abundant and widespread throughout the United States (Seward et al. 2004). Southern states harbor most of the pigs, but the distribution of wild pigs in the United States is quickly expanding to occupy suitable habitat (Gipson et al. 1997, Rollins et al. 2007, USDA 2012). Wild pigs include deliberate or accidentally released domestic (feral) pigs and their descendants, Eurasian wild boar that were introduced primarily for recreational hunting, and hybrids between feral and Eurasian pigs (Taylor 1991, Stevens 1996).

Wild pigs are responsible for a variety of types of damage including damage to crops, pastures, and lawns, and killing livestock (Choquenot et al. 1996; Taft 1999; Engeman et al. 2004, 2006, 2007; McCann and Garcelon 2008). Additional concern stems from the wild pigs' potential for disease transmission to food animals and humans (Davis 1993, Choquenot et al. 1996). Other potential problems associated with wild pigs are spread of invasive plant species, competition for resources with native wildlife, predation of native wildlife, contamination of water sources, alteration of soil properties, and erosion (Peine and Farmer 1990; Engeman et al. 2004, 2006; McCann and Garcelon 2008).

Regardless of their origin, wild pigs have proven they can adapt and flourish. This is likely in part due to their omnivorous food habits and high reproductive potential (Wood and Barrett 1979). Wild pigs can produce 4 to 8 piglets up to twice a year, leading to exponential population growth in good habitat (Mapson 2008). Selection for large litters in domestic animals and subsequent reintroduction of this highly adaptive, highly fecund organism into the wild supports a pig epidemic. The above characteristics explain growing populations in the wake of control efforts (Taylor 1991, Stevens 1996).

Efforts to control wild pig populations are increasing as wild pig/human conflicts increase (Williams 2011). The list of wild pig control strategies is diverse; often dependent on the landowner's or manager's goals, knowledge, and financial means. Lethal and non-lethal techniques are limited only by legality and imagination. Research suggests that trapping removes more pigs than ground hunting, hunting with dogs, and Judas pig techniques (McCann and Garcelon 2008). Euthanasia may be the only effective option for wild pig control as some pigs released into commercial hunting areas may be escaping through fences deemed pig-proof. More effective methods to control wild pig damage are needed (Sweeney et al. 2003, Campbell and Long 2009). Increasing efficacy with preferred techniques will improve control of pig populations.

In southern Oklahoma, standard corral or box traps are often used to capture wild pigs (Stevens 1996), but are generally ineffective for controlling pig numbers at the scale necessary to have significant, long-term effect on reducing populations (Williams 2011). Use of drop-nets has been documented for capturing multiple species (Jacobs 1958, Ellis 1961, Glazener et al. 1964, Ramsey 1968, Kock et al. 1987, Gee et al. 1999, Jedrzejewski and Kamler 2004), and has accomplished mass capture in areas of high density (Ramsey 1968). Use of drop-nets has not been documented for trapping wild pigs, but may be a viable alternative to conventional traps when population control is a goal.

LITERATURE REVIEW

## Damage

While some people welcome wild pigs as another recreational hunting opportunity, many consider them nuisance because of their destructive nature (Stevens 1996). Pigs are generalist omnivores, which allow them to utilize a variety of food sources in a broad range of environments (Taylor 1991). They destroy agricultural crops, pastures, farm equipment, livestock, lawns, and urban landscapes; all resulting in an economic burden to landowners or stakeholders (Choquenot et al. 1996; Taft 1999; Engeman et al. 2004, 2006, 2007; McCann and Garcelon 2008). Furthermore, they can promote spread of invasive plant species, predate on and compete with native wildlife, contaminate water sources, and impact soils (Peine and Farmer 1990; Engeman et al. 2004, 2006; McCann and Garcelon 2008). Some wild pig populations are intruding on endangered species and fragile ecosystems (Engeman et al. 2004, 2006; McCann and Garcelon 2008). Wetlands and seepage slopes can be particularly vulnerable (Engeman et al. 2004, 2006; McCann and Garcelon 2008). The greatest economic losses to wild pigs are found in crop farming systems (Tisdell 1991). Other areas affected include residential, golf courses, native rangeland, and forests (Taylor 1991, Choquenot et al. 1996; Taft 1999; Engeman et al. 2004, 2006, 2007; McCann and Garcelon 2008). Wild pigs damage pasture and agricultural crops by consumption, rooting, digging, and trampling (Seward et al. 2004). Pimentel et al. (2002) found one pig caused approximately $200 in agricultural crop damage each year. Farmers report damage to agricultural crops such as hay, corn, peanuts, small grains, milo, rice, and wheat (Rollins

1993). Other crops affected are vegetables, watermelons, soybeans, cotton, orchards, horticultural crops, and conifer seedlings (Rollins 1993). Little research exists on the economic losses due to wild pigs in native ecosystems (Engeman et al. 2004, 2006, 2007), and monetary values are difficult to obtain. Engeman et al. (2007) estimated value of damage based on the dollar amounts wetland regulators have charged permit applicants to mitigate their damage to wetland resources.

**Reproduction and Home Range**

Pigs possess the highest reproductive potential of any large mammal in North America (Wood and Barrett 1979, Hellgren 1999). They are capable of producing 2 litters per year with average litter size varying from 4 to 8 piglets (Taylor et al. 1998), but as many as 10 piglets can be born during ideal conditions (Choquenot et al. 1996). Wild pigs travel in family groups called sounders, which consist of 1 or more sows and their young (Mapson 2008). Mature boars are usually solitary, only joining a sounder to breed (Taylor 1991, Stevens 1996). Wild pigs' home ranges can vary from 0.64 to 30 $km^2$ depending on habitat condition, with sounders typically occupying smaller home ranges than mature boars in similar habitats (Stevens 1996). Wild pigs readily inhabit many vegetation types, but prefer moist bottomlands, riparian areas, and dense vegetation (Stevens 1996). Habitat selection of wild pigs is affected by thermoregulation requirements (Ilse and Hellgren 1995; Cooper et al. 2010). With the absence of sweat glands, pigs have to find moist areas to cool off during warm periods (Campbell and Long 2009). Daily movements and selection of vegetation types are generally associated with availability of water. Wild pigs favored areas near water in all seasons and riparian areas in all seasons except winter (Cooper et al. 2010). Recent improved distribution of water on rangeland brought about by construction of additional water points for livestock and wildlife, especially white-tailed deer (*Odocoileus virginianus*), is likely to be a major contributor to the expansion of wild pig populations into rangeland (Mapston, 2008).

**Disease**

Wild pigs have been documented to carry or transmit many diseases of importance to livestock and human health such as brucellosis, leptospirosis, tuberculosis, porcine parvovirus (PPV), porcine reproductive and respiratory syndrome (PRRS), hog cholera, and pseudorabies virus (PRV) (Davis 1993, Choquenot et al. 1996). Other exotic diseases such as foot-and-mouth could have disastrous effects on our economy if an outbreak were to occur in wild pig populations (McIlroy 1995, Choquenot 1996). Oklahoma wild pigs have been tested for many of these diseases. In 1996, Saliki et al. (1998) collected samples from 120 wild pigs in 13 Oklahoma counties. They found antibodies to suggest leptospiral infection in 44% of the samples, PPV and swine influenza virus antibodies in 17 and 11% of the samples, respectively, and antibodies against PRRS in 2% of the samples. No antibodies to swine brucellosis, PRV, transmissible gastroenteritis, and vesicular stomatitis were detected in previous studies in Oklahoma. I focused on 3 specific pathogens of concern to the commercial swine industry; PRV, brucellosis, and PRRS.

PRV is a herpesvirus, sometimes referred to as Aujeszky's disease or mad itch. PRV infects the nervous system of livestock, as well as many species of wildlife (APHIS

2012). In most species, infection rapidly leads to death with mortality rates approaching 100%. Only pigs are able to survive an acute infection and they represent the natural reservoir for the virus (Mettenleiter 1996). In swine, symptoms vary from asymptomatic to fatal (Davidson and Nettles 1988). Young pigs may experience fever, vomiting, tremors, convulsions, loss of coordination, and death (Davidson and Nettles 1988). Adult pigs rarely die, but may display fever or upper respiratory inflammation (Davidson and Nettles 1988). Pirtle et al. (1989) found that antibodies to PRV occurred primarily in adults with little evidence of seroconversion of maternal antibodies in juvenile feral swine. Infection of pregnant sows results in abortion or mummified fetuses (Davidson and Nettles 1988). Transfer of PRV among swine may occur by nasal and oral secretions, contaminated aerosols, food, water, or environmental structures (Davidson and Nettles 1988). Romero et al. (2001) provide evidence for venereal transmission as the most important route of natural transmission of PRV in both free-ranging feral and domestic swine. Providing artificial water or supplemental forage may cause addition risk of indirect transmission (Vicente et al. 2007). Since it produces abortions and piglet deaths, the commercial pork industry spends millions of dollars annually in detection and prevention of PRV (Davidson and Nettles 1988).

Swine brucellosis is caused by the bacterium *Brucella suis*. Bovine brucellosis is caused by the bacterium *Brucella abortus*. Wild pigs are capable of contracting both of these (Ebani et al. 2003). Swine brucellosis is primarily a reproductive tract disease that causes abortions, stillborn pigs, infertility, inflammation of testicles, and lameness (Davidson and Nettles 1988). Infected pigs are long-term carriers and can infect other wildlife, livestock and humans (Davidson and Nettles 1988). Identifying infected populations and prohibiting relocation of infected wild pigs to new areas is important for controlling the spread of brucellosis. Hunters can contract the disease when handling carcasses (Davidson and Nettles 1988). Bovine brucellosis causes abortion, infertility, and reduced milk production in cattle (Davidson and Nettles 1988).

PRRS virus causes late-term reproductive failure and post-weaning respiratory disease in pigs (Veterinary Services 2009). PRRS has a high mutation rate, which can make the virus difficult to control (Veterinary Services 2009). Transmission occurs through pig-to-pig contact and some strains can aerosolize over short distances (Veterinary Services 2009). The virus often is found in saliva, nasal secretions, urine, feces, needles, and semen (Veterinary Services 2009). Indirect transmission can occur through insects (Veterinary Services 2009). The practice of providing artificial water or supplemental forage may cause an increased risk of indirect transmission (Vicente et al. 2007).

**Control Methods**

Control of wild pigs has become a topic of concern among farmers, ranchers, and wildlife managers. Lethal and non-lethal control techniques are diverse and include fencing (Geisser and Reyer 2004, Reidy et al. 2008), harassment, contraception, snaring, poisoning, sport hunting, aerial shooting, and trapping (Diong 1980, Choquenot et al. 1993, Sweeney et al. 2003). There are no contraceptives or toxicants registered with the Environmental Protection Agency for use on wild pigs in the U.S. (Campbell and Long 2009). Control techniques must conform to statewide legal requirements, as different states inadvertently restrict nuisance control practices with regulation of other species. Electric fences have been found to only reduce, not exclude, intrusions by wild pigs (Geisser and Reyer 2004, Reidy et al. 2008). Recreational hunting is ineffective in remote areas (Hone 1984, Ohashi, 1988). In addition, population control through hunting alone is more difficult than with other techniques because of restricted access to pigs in dense cover and reduced hunter motivation when wild pig densities fall (Cruz et al. 2005, McCann and Garcelon 2008). Strategies to increase hunting effectiveness include "Judas pigs" (McIlroy 1995, McCann and Garcelon 2008) and hunting with dogs (McIlroy 1995). "Judas pigs," which take advantage of pigs' gregarious nature and incorporates radio collars affixed to captured pigs to disclose the position of other pigs, increased harvest from helicopters in the Northern Territory of Australia, increased harvest with dogs in New Zealand, but was unsuccessful subsequent to warfarin-poisoning campaigns in Australia (McIlroy 1995). Hunting wild pigs with dogs was not found to be as effective as trapping, shooting from helicopters, or poisoning in Australia (McIlroy 1995). Since dogs are not effective at capturing large groups of pigs, hunting with dogs may be most appropriate to capture pigs remaining after implementation of other techniques.

Trapping is often determined the most effective control technique (Sterner and Barrett 1991). Trapping is most effective in reducing pig numbers when densities are high (Garcelon et al. 2005). Cage type traps are commonly used to trap wild pigs in Oklahoma, and of these traps, the corral trap is most popular (Stevens 1996). However, Diong (1980) documented trap wariness to box and corral traps. Corral traps have been supplemented with estrous-induced sows in attempts to increase effectiveness. Sows in estrous are placed inside an enclosure or additional compartment in conventional corral traps, in hopes that they will attract boars into traps. These efforts have documented little success (Choquenot et al. 1993). Research suggests there is value in using a variety of techniques in an integrated fashion (McCann and Garcelon 2008, Campbell and Long 2009). Persistent pig numbers despite significant control efforts, necessitate the pursuance of efficient and cost effective alternative trapping methods.

Drop-net traps were first described to capture prairie chickens (*Tympanuchus cupido*; Jacobs 1958). The trap's usefulness expanded to capture wild turkey (*Meleagris gallopavo;* Ellis 1961, Glazener et al. 1964), white-tailed deer and axis (*Axis axis*) deer (Ramsey 1968), bighorn sheep (*Ovis canadensis*; Kock et al. 1987), and red deer (*Cervus elaphus*; Jedrzejewski and Kamler 2004). The drop-net has been used as a means of mass deer capture in areas of high density (Ramsey 1968). No research exists on the application of drop-nets to capture pigs, however, several modifications recently have been developed to simplify techniques and reduce costs (Silvy et al. 1990, Lopez et al. 1998, Gee et al. 1999). No research exists on the efficacy of drop-nets for wild pig control.

OBJECTIVES

I researched the application of drop-nets for mass wild pig capture. My first objective was to compare the efficacy of drop-nets and corral traps for capturing wild pigs in southern Oklahoma. My second objective was to determine if wild pig removal reduces damage on native rangelands invaded by old world bluestems. My third objective was to determine the exposure rate to 3 viral or bacterial diseases; PRV, PRRS, and brucellosis.

# CHAPTER II

# EFFICACY OF METHODS

## INTRODUCTION

Since their introduction to the United States, expanding populations of wild pigs (*Sus scrofa*) have negatively impacted land and natural resources. Their presence has resulted in biodiversity and agricultural commodity losses, depredation of native flora and fauna, destruction of habitat, disease transmission, and other public safety issues (Peine and Farmer 1990; Choquenot et al. 1996; Taft 1999; Engeman et al. 2004, 2006, 2007; McCann and Garcelon 2008). The wild pig's reproductive potential and adaptability to a broad range of habitats explains persistent populations and continuous damage in the wake of conventional control efforts (Taylor 1991). Research suggests that removal by trapping is more effective than other pig control techniques (McCann and Garcelon 2008).

Wild pig trapping techniques are diverse, ranging from using snares to small box traps to very large corral traps (Diong 1980, Choquenot et al. 1993, Sweeney et al. 2003). Traps vary in shape, incorporate many different materials, and have 1 or more openings with various gate designs (Taylor 1991, Stevens 1996). Many techniques assume that pigs will become habituated to a consistent food source. These techniques use bait to attract pigs to a particular area where an enclosure is set up and pigs are trapped by activating a gate or trigger. Pre-baiting, habituation to the trap and subsequent trapping of the pigs generally occurs over a time span of several days, if not weeks (Taylor 1991, Stevens 1996). Many trappers argue that pigs become trap-shy to many trap types, which in turn forces them to change bait type, trap shape, trap size, trap location, door design, trip wire design, or give up. Diong (1980) reported that pigs may be apprehensive about entering the traps. Many trapping methods are not effective at controlling wild pigs at the scale necessary to have significant, long-term effect on reducing populations (Choquenot et al. 1993, Williams et al. 2011).

One of my objectives was to determine the effectiveness of drop-nets for capturing wild pigs. Casual experience using drop-nets to capture wild pigs indicated that drop-nets might be a viable alternative to conventional trapping techniques when population control on a ranch size scale is the goal. Unlike conventional corral traps that are generally triggered by the animal, drop-nets are manned and capture pigs by entangling them. Drop-nets have been used to capture numerous wildlife species and are often very effective at capturing large numbers of animals in 1 drop (Jacobs 1958, Ellis 1961, Glazener et al. 1964, Ramsey 1968, Kock et al. 1987, Jedrzejewski and Kamler 2004). To determine the effectiveness of drop-nets for wild pig capture, I compared its use with the most popular trap type used in the region of study, the corral trap (Stevens 1996).

In addition to the determination of trap effectiveness, trap efficiency was also investigated. Efficiency is defined as the effective operation as measured by a comparison of production with cost (as in energy, time, and money; Merriam-Webster 2012). I compared trapping success with time allocated to each trapping technique. I used time because activities that require more physical labor, skill, or thought generally require more time to accomplish. The extra effort is rectified by adding time.

Measuring effort invested in trapping systems is not a new practice (Bordalo-Machado 2006). The "Catch Per Unit Effort" (CPUE) concept is commonplace in fisheries stock assessments, where efficiency is an index to population trends. In my study, I compared efficiency between trapping techniques. Efficiency is affected by skill or technical advantage of one system over another (Pascoe and Robinson 1996). I determined which technique was more efficient and what those advantages were. Efficiency in capturing wild pigs may be greatly increased when using methods to target multiple pigs or even entire sounders at once. I hypothesize drop-nets will be more efficient than corral traps because of their capability of capturing entire sounders with little time investment (1 drop).

## STUDY AREA

This 2-year study was conducted at the Noble Foundation (NF) Oswalt Road Ranch (ORR), NF Coffey Ranch (CR), and Bill Hoffmann's ranch (HR) in Love County, Oklahoma (Fig. 1). The study sites are in the Cross Timbers and Prairies eco-region, which is characterized by a mixture of wooded areas and openings. Wooded areas in the Cross Timbers and Prairies eco-region are often dominated by various oaks *(Quercus spp.)*, elms *(Ulmus spp.)*, and hickories (*Carya spp.*; Gee et al. 1994). Bottomlands are often dominated by oaks, ashes *(Fraxinus spp.)*, elms, hackberries *(Celtis spp.)*, and osage orange (*Maclura pomifera*; Gee et al. 1994). Open areas typical of the Cross Timbers and Prairies eco-region often include grasses such as bluestems *(Andropogon spp.)*, switch grass *(Panicum virgatum)*, and Indian grass *(Sorghastrum nutans)*, as well as numerous forbs (Gee et al. 1994). Very shallow upland sites with limestone bedrock were common on ORR. These sites were dominated by gramas *(Bouteloua spp.)*, bluestems, dropseeds *(Sporobolus spp.)*, and Texas wintergrass *(Stipa leucotricia).* Shallow upland sites had a plethora of annual and perennial forbs associated with them as well. Invasive species including old world bluestem (*Bothriochloa ischaemum*), jointed goatgrass (*Aegilopis cylindrica*), and bromes (*Bromus spp.*) were abundant across ORR. CR was comprised of native rangeland and some tamed pasture with species including bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halapense*). Sandstone hills with exposed rock were common on HR. Greenbriar (*Smilax bona-nox*) was abundant across HR.

The Samuel Roberts Noble Foundation (NF) has owned and managed CR since 1987. Wild pigs were first observed on the ranch in the mid 1990's. In 2000, NF took ownership of ORR. Bill Hoffmann owns HR. It is unknown when pigs were first observed on ORR or HR. Past wild pig management included drop-nets and corral traps on ORR, corral traps on CR, and shooting on HR. All hunting and trapping of wild pigs was prohibited during 1 calendar year prior to my study. Total area of the 3 ranches was approximately 4047 ha.

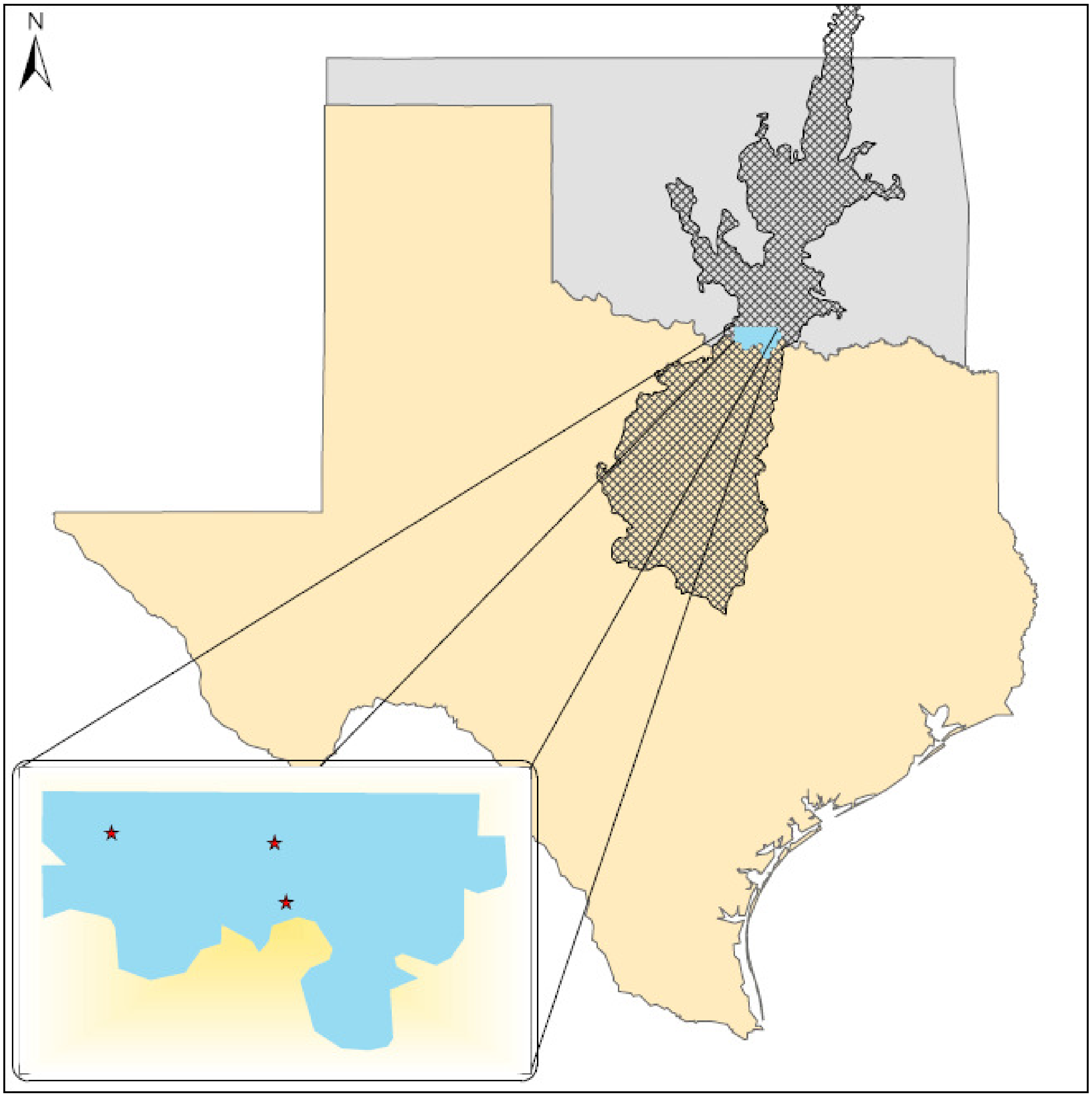


Figure 1: Study sites (stars) in Love County (inset) within the Cross Timbers (shaded) ecoregion stretching from Oklahoma to Texas, 2010.

METHODS

**Effectiveness**

*Camera Surveys.* I identified photo points on ORR(n=40), CR (n=26), and HR (n=23) in Love County, Oklahoma, USA. Photo points included a t-post, feed tub baited with corn, site number, and a trail camera. A 7-day pre-baiting period preceded a 7-day camera survey. No photos were taken during the pre-baiting period, but I replaced bait daily as needed. I collected pictures for a 7-day period between 1700 and 0800 h following the pre-baiting period. Cameras were set with a delay so they collected 1 photo every 10 min when animals were present.

The pre-baiting period for 40 sites on ORR began on 1 January 2010 and 2011. I set forty infrared-triggered cameras to take pictures 8 January-15 January. I began pre-baiting 20 sites on CR and 20 sites on HR on 1 February. Forty infrared-triggered cameras were moved from ORR to CR and HR for the camera surveys that followed on those 2 ranches simultaneously. Survey period began 8 February on CR and HR. I used camera surveys to determine areas of highest pig density to optimize trapping efforts. In addition, I documented sounder demographics and unique individuals to aid in individual pig identification at sites later considered for trapping. Photos taken of pigs during the camera surveys served as a reference to help positively identify pigs during trapping.

*Trapping.* The ORR, CR, and HR were divided into a total of 6 units. Treatments were randomly assigned to the 6 units resulting in 2 units being trapped with corral traps, 2 with drop-nets, and 2 units served as no harvest controls. ORR was trapped with corral traps in the east unit and drop-nets in the west unit. CR was trapped with drop-nets in the east unit and served as a no harvest control in the west unit. HR was trapped with corral traps in the east unit and served as a no harvest control in the west unit. Treatments remained the same in year 2. Trapping was conducted in January - April when natural forage was less available.

Corral traps consisted of 2 adjoining compartments with 2 different gate openings facing opposite one another (Fig 2). These traps were capable of capturing additional pigs in the adjacent compartment once one half was already tripped. Corral traps were constructed with t-posts (1.8 m) and 4.9 m cattle panels with mesh size 10 cm by 10 cm. Panels were 1.5 m in height. Each compartment consisted of 2(4.9 m) panels and a randomly assigned gate type; saloon style or single spring. Each trap incorporated both gate types to examine any differences in pig response. Each gate had solid metal plate welded from 0-30 cm height to allow pigs to enter by pushing open gates in the closed position. The 2 compartments shared a 2.4 m rear panel. The 4.9 m side panels necked down from the rear panel to the width of the door (Fig 2). T-posts were driven into the ground every 1.5 m around the trap and panels were securely fastened to them at every 20 cm in height with medium gauge soft metal wire.

I used the drop-net system described by Gee et al. (1999) for drop-net applications and incorporated an 18.3 X 18.3 m net. The drop-net required human presence to trap. The system incorporates multiple rope harnesses, a release mechanism, solenoids, batteries, and a line-of-sight remote control to trigger the net to drop. I actuated the trigger on a drop-net remote by moving a slide control switch to the on position. I stored remote controls for drop-nets in a weather proof box. I used a Trailmaster active infrared trail monitor (TM 1050, Goodson & Associates, Inc., Lenexa Kansas, USA) in combination with a radio frequency transmitter and 2-way radio to monitor activity under nets; thereby eliminating the need for constant observation. The drop-net system also was equipped with a remote controlled infrared-filtered spotlight (Trailmaster, Goodson & Associates, Inc., Lenexa, Kansas, USA) which facilitated nighttime use. Whole kernel corn was used to bait all traps. Bait (16 kg) was replaced daily as needed.

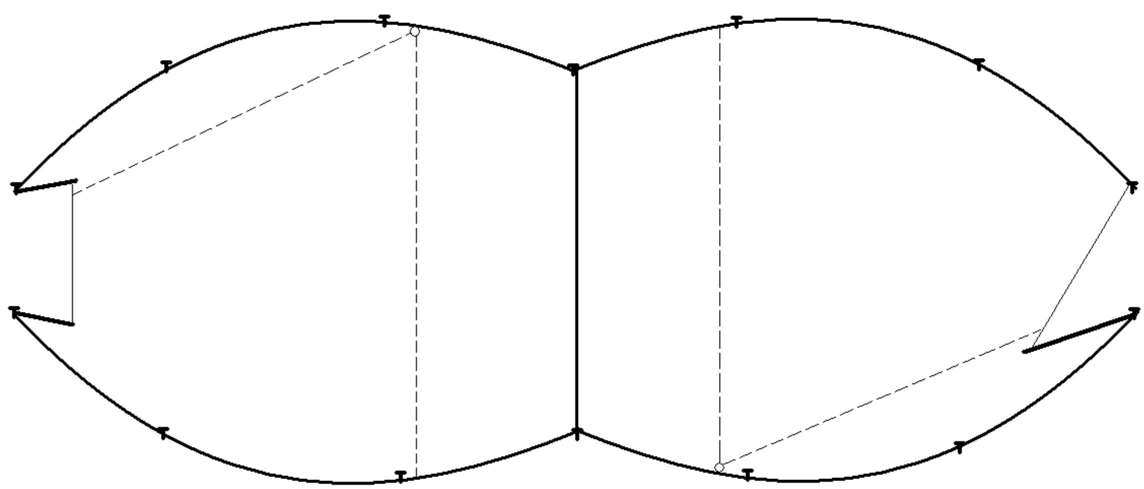

Figure 2: Corral trap configuration including gate styles (far right and left) and trip wires (dotted) used on Oswalt and Hoffmann Ranches, Love County, Oklahoma, USA, 2010-2011.

After the camera surveys were finished on ORR, CR, and HR, 3 days rest was given without bait to attempt to redistribute pig densities before trapping. Three days allowed all remaining bait to be consumed and pigs' opportunity to search new areas for food. Trap sites were not pre-determined. They were identified where wild pig presence was documented during camera surveys. Areas with highest pig densities observed in camera surveys were targeted first for trapping. Multiple sites within each treatment were trapped simultaneously.

Once a trap site was determined, the site was pre-baited for 7 days, and if ≥1 pig was patterned (consumed bait in ≥ 3 consecutive days) during the pre-bait period, a trap was set up. Still and video cameras (Cuddeback NoFlash, Non Typical, Inc., Green Bay, WI, USA) were set up on all trap sites (not to be confused with camera survey site) to facilitate individual pig identification, determine identifiable pig population estimates, document pigs' responses to trapping events, monitor residual pig activity at the traps, and assess need for trap relocation. Trap site pre-baiting occurred for both trap type treatments. Before traps were set up, approximately 16 kg of corn was placed in 1 pile at each trap site. At first, corral trap gates were tied open (3 days minimum) to allow pigs to become familiar with the trap. I poured a line of corn from outside of the corral traps, through the gates, and towards the back of the traps. When pigs consumed the bait and photos documented pig presence inside the corral trap, 16 kg of corn was placed only in the rear half of the corral trap compartments. A horizontal trip wire (2 mm braided cable) was stretched across each compartment 40 cm from the rear at 30 cm height. The trip wire was routed through a 2.5 cm pulley and connected to a prop stick holding the gates open (Fig. 2). Corral traps were baited every day, pigs removed, and traps reset until monitoring cameras showed no further pig activity. Corral traps were abandoned and relocated once 5 consecutive no catch days had occurred. Corral traps were relocated until monitoring cameras detected no additional pigs in the treatment unit. After set-up, drop-nets (Fig. 3) were baited only around the center pole. Approximately 16kg of corn was placed in 4 or 5 small piles (Fig. 3) surrounding, but less than 1-m away from, the center pole. While trapping wild pigs with drop-nets, the lowest point in the net or sag between the corner poles, was kept $\geq$ 1.2 m. Dropping from this height did not allow pigs space to escape falling nets and did not interfere with pig movement into the trapping area. Drop-nets could be trapped the night in which they were set up. Subsequent trapping of previously triggered drop-nets occurred if pig visitation was documented for 3 consecutive days. Drop-nets were observed when pigs were patterned, manually dropped, baited daily, and reset when dropped until monitoring cameras showed no further pig activity. Since a camera is part of the drop-net system, net sites were abandoned and relocated once 5 consecutive "no pig picture" days had occurred.

Trapping technique, location, number of pigs trapped, sex, weight, and approximate age were recorded for each pig or group of pigs trapped. Females greater than 25-30 kg are considered capable of breeding in good dietary condition (Choquenot et al. 1996). I assigned age classes based on body weight as juvenile (0-27 kg) or adult (>27 kg). Trapping efforts concluded before 30 April or when no more pigs were being observed at sites throughout the individual treatment areas. Captured wild pigs were euthanized by brain shot while in the trap using a .22 caliber rifle with full cap ammunition. No other pig harvest or removal was allowed on the study areas.

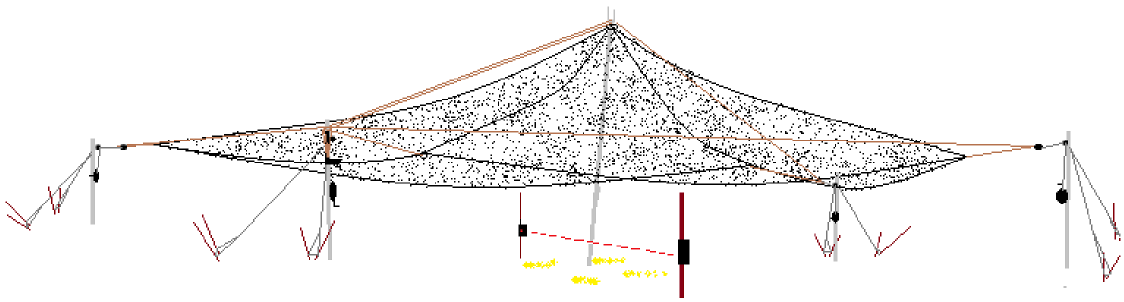

Figure 3: Drop-net configuration including net, rope harnesses, support poles, deadmen (anchors), infrared trail monitor, and bait placement used on Coffey and Oswalt Ranches, Love County, Oklahoma, USA, 2010-2011.

*Mark-recapture.* Following other studies that used infrared-triggered cameras to census wildlife based on identifiable subjects (Jacobson et al. 1997, McKinley et al. 2006) I developed a tool for estimating the identifiable segment of pig populations to test trap effectiveness. Using the Lincoln-Petersen mark-recapture equation, I obtained an identifiable pig population estimate at each trap site (Petersen 1896, Lincoln 1930). These estimates did not include indistinguishable pigs. Photographic data from camera surveys indicated I could identify >35% of wild pigs in my study area. Marking pigs consisted of documenting and identifying all unique identifiable pigs visiting a trap site using trail camera photographs taken 5 days prior to trap setup. In my study, the identifiable segment of the population refers to all individuals or groups in the population that include unique pigs with distinguishable color markings, scars, or deformities that were documented on trail camera photographs. For example, an identifiable pig may be multicolored with a discernible pattern or possess a distinct scar. Identifiable sounders were also considered as part of the identifiable segment of the population. Sounder demographics such as pig size and number assisted in identifying identifiable sounders. For example, an identifiable sounder may consist of a specific number of generic looking individuals with a specific size distribution that consistently used a bait site until trapped. For mark-recapture calculations and analysis, the recapture period consisted of the period that traps were set.

Photos of both sides of each trapped pig were taken to facilitate individual hog identification and comparison to the identifiable pig population documented during "mark" period. I evaluated photos and video to identify unique pigs marked in the trap site "mark" period and marked and unmarked unique pigs trapped in the "recapture" period. Trap effectiveness was calculated as the ratio of identifiable captures to the Lincoln-Petersen identifiable pig population estimate. Trap effectiveness was calculated by trap site and trap type. Calculation by trap type accounted for pigs using multiple sites or pigs that were missed in a first attempt, but were captured after the traps were relocated. If an identified pig was using 2 trap sites simultaneously, and was captured at 1 site, that pig was removed from analysis of effectiveness of the other site. If an identified pig used 2 trap sites, but the period of time the traps were active did not overlap, that pig was used in analysis of effectiveness for both sites.

**Efficiency**

Trap type capturing efficiency by trap site was compared between drop-nets and corral traps. All time and a description of work done (activity) during this pre-bait period, during trap construction, trapping, and trap disassembly was recorded, as described below. Trap sites within the boundaries of treatment unit 1 were trapped with the treatment randomly assigned to treatment unit 1, and any recorded activity would coincide with that treatment and that site number. If potential sites were baited and pigs did not appear in the pre-bait period, time and activity was still charged against that trap site and type.

Detailed daily records were kept on the amount of time spent throughout the trapping process. Time records started when the vehicle entered a ranch and ended when it left the ranch. Data collected included date, ranch, treatment (trap type), trap site, activity description (e.g., baiting, trap setup or repair, travel, trapping, loading pigs), numbers of people present, and time elapsed. A new record started when activity changed, so I could categorize all time entries by activity. These records were used to calculate CPUE for each trap site and trap type.

**Statistical Analysis**

Effectiveness was calculated for individual trap site and collectively by treatment on each property. Effectiveness was analyzed using the PROC MIXED procedures of SAS® 9.2 (SAS Institute, Inc., Cary, NC). I used general linear mixed models (GLMM) to test whether effectiveness (response variable) was influenced by the type of trap used (trap type was a categorical variable with 2 levels; net and corral). Effectiveness was a proportion; therefore, I used an arcsine-square root transformation to normalize the response variable for statistical tests. To make general inferences across ranches and years, I specified 3 random effects: year, ranch, and site (ranch). I used a Kenward-Roger denominator degrees of freedom adjustment (Kenward and Roger 1997) to account for unbalanced data, multiple random effects, and models with correlated errors (Littell et al. 2006). Residual plots were visually inspected to assess whether data were normally distributed.

RESULTS

**Effectiveness**

I captured 356 pigs in spring of 2010 ($n$ = 222) and 2011 ($n$ = 134). Drop-nets were responsible for capturing 173 and 123 pigs in 2010 and 2011, respectively. Corral traps caught 49 and 11 pigs in 2010 and 2011, respectively. I documented maximum captures of 27 and 15 pigs with drop-nets and corral traps, respectively. Mean capture per successful trapping event was 10.7 and 3.8 in drop-nets and corral traps, respectively. Mean capture per trap site (which included multiple capture events) was 19.7 and 5.5 in drop-nets and corral traps, respectively.

Mean trap site effectiveness throughout my study was 67.3 and 28.2% for trap sites using drop-nets (n=15) and corral traps (n=11), respectively. Site effectiveness was 139% greater when using drop-nets compared to corral traps ($F_{1,17} = 6.18$, $P = 0.024$). A maximum of 5 capture events per trap site (before relocation) were achieved with both drop-nets and corral traps. Effectiveness by trap type was 85.7 and 48.5% for drop-nets and corral traps, respectively. Trap type effectiveness was 77% greater for drop-nets compared to corral traps. I observed a reduced trapping effectiveness on all 3 ranches from year 1 to year 2. With drop nets, I captured 90.0 and 81.3% of the identifiable pig population in 2010 and 2011, respectively. With corral traps, I captured 60.6 and 36.4% of the identifiable pig population in 2010 and 2011, respectively. I observed a reduced trapping effectiveness on all 3 ranches from year 1 to year 2 (Table 1). Table 1 shows ranch effectiveness for trapping treatments on all 3 ranches. Population estimates in the table appear low, but are only estimates of the identifiable segment of the pig population. These estimates do not include indistinguishable pigs in the study area. Mean identifiable pig population estimates at trap sites was 10 and 18 in 2010 and 2011, respectively. Sum of identifiable pig population estimates at trap sites was 183 and 129 in 2010 and 2011, respectively.

Table 1: Ranch effectiveness for treatment (drop-net and corral trap) on Coffey, Hoffman, and Oswalt Ranches, Love County, Oklahoma, USA, 2010 and 2011.

| | | | Totals | | | | |
|---|---|---|---|---|---|---|---|
| Year | Trap type | Ranch | Marked | Unique trapped | Marked trapped | Pop. est. | Ranch effec. |
| 2010 | Drop -net | Coffey | 55 | 55 | 51 | 59.31 | 0.9273 |
| | | Oswalt | 63 | 55 | 55 | 63 | 0.8730 |
| | Corral | Hoffmann | 11 | 8 | 8 | 11 | 0.7273 |
| | | Oswalt | 17 | 15 | 8 | 31 | 0.4839 |
| 2011 | Drop -net | Coffey | 51 | 50 | 47 | 54.25 | 0.9217 |
| | | Oswalt | 54 | 39 | 38 | 55.41 | 0.7038 |
| | Corral | Hoffmann | 11 | 4 | 4 | 11 | 0.3636 |
| | | Oswalt | 0 | 0 | 0 | 0 | NA |

I observed no differences in catch rate when comparing saloon style gates to single spring gates on corral traps. Throughout my study, 32 and 28 pigs were captured in saloon and single spring gates, respectively. In my study, rooter plates on the bottom of corral trap doors did not increase catch rate by allowing more pigs to enter after the initial closure. No pigs entered closed gates on corral traps during this study.

Juveniles accounted for 55% of total pigs captured in my study. Captured juvenile sex ratio was 1.1 female to 1 male. Forty -two and 26% of the captured adult pigs were male in drop-nets and corral traps, respectively. Corral traps were not used at

ORR in year 2 because no pigs were observed in the camera survey or in the additional monitoring period to locate pigs.

I recorded 93 falsely triggered corral trap gates during my project. Species captured or suspected of triggering gates included white-tailed deer (*Odocoileus virginianus*; n=27), raccoons (*Procyon lotor*; n=1), cattle (*Bos taurus*; n=3), and numerous bird species (n=7). One drop-net was accidentally dropped while trapping. This accidental drop occurred when the slide control switch struck the side of the weather proof box upon insertion. No animals were under the net when the trigger was actuated.

I observed still and video recordings from cameras set to monitor pigs' responses to trapping events. Photos taken within 24 hrs after corral trap setup identified more hesitant than non-hesitant behavior in wild pigs near the trap. Hesitant behavior included consuming bait up to the gate opening but not inside the trap and leaving the trap without consuming any bait inside or outside. Non-hesitant behavior included consuming bait for an extended (>20 min) period of time and entering and consuming bait from inside the trap. I observed a variety of reactions (more to less frequent) to pigs' first encounter with drop-nets; no hesitation, hesitant and entered, and hesitant and left. Frequency of these reactions was difficult to obtain as differences were observed at the sounder and individual pig level. While some pigs looked up at the net, others moved in to bait with no hesitation. It was rare for an identified pig or sounder to hesitate before entering a drop-net > 3 days after setup. By day 3, pigs that at first hesitated, were used to the net.

Lots of noise and panic resulted from the triggering of both trap systems. Every pig capture with corral traps resulted in loud vocalizations and running and jumping into all sides of the trap. This behavior continued for approximately 5 min. Occasionally, wire was loosened or broken from the panels where fastened to t-posts. Uncaught pigs reacted to corral trap gate closures in a couple different ways. One reaction was pigs fled the site, returning to the trap later, and remaining near the trapped pigs until I arrived to collect them. More often, uncaught pigs did not return to corral traps after gates were triggered. Many identified pigs that regularly visited corral traps before a trapping event were not recorded on monitoring cameras after being in the vicinity of a corral trap when it was triggered. Every drop-net capture resulted in loud vocalizations, running, and jumping under the net until pigs were tangled, motionless, and euthanized. Pigs were euthanized within 5 min. of the drop. Since I waited for entire sounders to enter the drop-net before triggering it, extended reactions of non-captured pigs could rarely be determined. Some pigs not caught in initial drop-net captures were caught in subsequent captures. Some were not.

Escapes were observed in both trapping systems. Seven and 9 % of captured pigs escaped before being euthanized in drop-nets and corral traps, respectively.

**Efficiency**

I recorded 1,507 activity records for trapping related activities such as baiting, trap construction and maintenance, removing and loading pigs, and trap observation (Figs. 4 and 5). Initial trap setup took 2.2 and 2.6 man hours for drop-nets and corral traps, respectively. Driving t-posts was the most time consuming portion of drop-net setup. Wiring panels to t-posts was the most time consuming portion of corral trap setup. Construction and maintenance of erected traps during their entire trapping period took 5.09 and 4.27 man hours per site for drop-nets and corral traps, respectively. Trap observation was only necessary for the drop-net treatment. For drop-nets, mean trap observation time, regardless of whether there was a capture, was 3.9 man hours. On a yearly basis, the 2010 and 2011 CPUEs for drop-nets were 2.36 and 1.21 hrs per pig, respectively. Corral trap CPUEs for 2010 and 2011 were 2.44 and 1.73 hrs per pig. Overall CPUEs for drop-nets and corral traps were 1.88 and 2.31 hours per pig, respectively. Fourteen percent less effort was required to capture 1 pig with drop-nets than corral traps.

Drop-net systems cost approximately \$3,500 while corral trap systems described in this study cost approximately \$500. In this study, average cost efficiency per trap site was \$178 and \$91 per pig in drop-nets and corral traps, respectively.

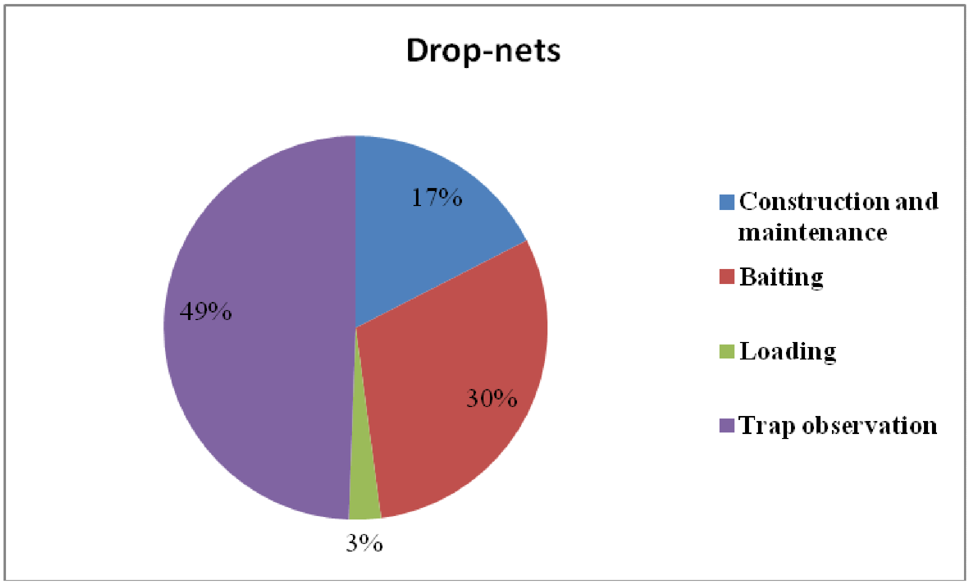


Figure 4: Proportion of time spent (on various activities) while trapping with drop-nets on Coffey, Hoffmann, and Oswalt Ranches, Love County, Oklahoma, USA, 2010 and 2011.

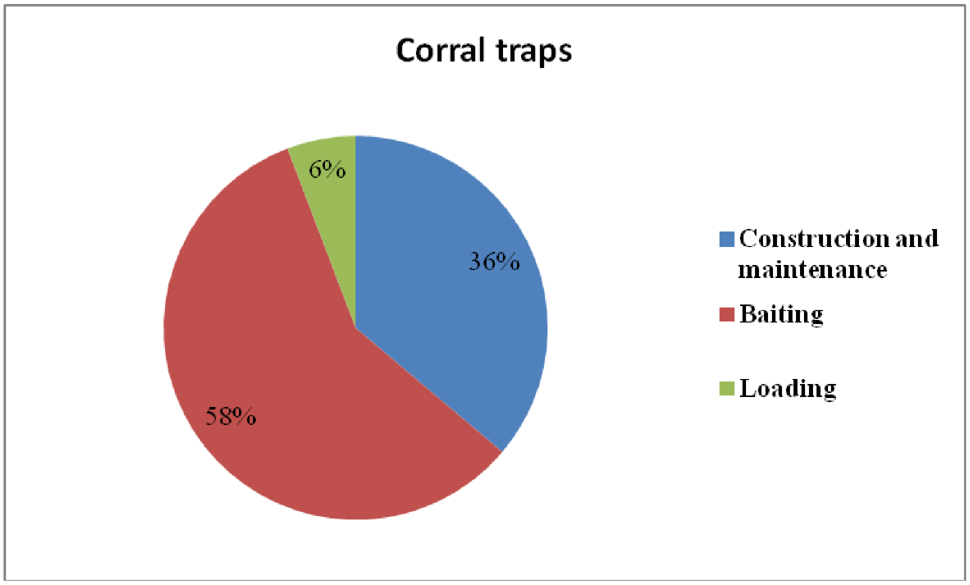


Figure 5: Proportion of time spent (on various activities) while trapping with corral traps on Coffey, Hoffmann, and Oswalt Ranches, Love County, Oklahoma, USA, 2010 and 2011.

## DISCUSSION

My study examined the novel use of drop-nets to capture wild pigs. Drop-nets have a long and successful history with capture of other ungulates (Ramsey 1968, Kock et al. 1987, Jedrzejewski and Kamler 2004). I found the drop-net technique to be a successful capture technique on wild pigs with high CPUE, minimal escapes, selective capture capabilities (because an operator controls the drop), and ability to remove a large proportion of the identifiable pig population (based on development of a 'site effectiveness' variable). To account for variable pig populations and time spent using each capture technique, I developed a new response variable to overcome these analytical limitations. The development of a ‘site effectiveness’ variable overcame many of these difficulties and can be used under similar situations for a wide range of species. I also used a new approach to estimate identifiable pig populations, based on identification of uniquely colored or physically distorted (e.g., scars, cuts, amputations, other injuries) individuals which can serve as “marked” individuals in the application of a mark-recapture population estimation procedure. Other studies have used infrared-triggered cameras to survey white-tailed deer based on identifiable subjects (Jacobson et al. 1997, McKinley et al. 2006). Physical features such as antler characteristics also have been used as an index for estimating populations (Jacobson et al. 1997).

**Whole Sounder Approach**

Most conventional trapping methods, including corral traps, are not effective at controlling wild pigs at the scale necessary to have significant, long-term effect on reducing populations (Choquenot et al. 1993, Williams et al. 2011). Often, a portion of a sounder may enter and trip corral traps leaving a majority of the sounder outside the traps. Trigger placement and type may inconsistently allow larger groups into corral traps before gates are tripped. Successfully trapping wild pigs with corral traps also may require accurately predicting pig behavior. Using animal-activated triggers eliminated trapper presence, but observational data suggested that successfully capturing large groups of pigs with corral traps was contingent on baiting technique, trigger mechanics, and pig behavior in and around traps. It is highly advantageous to be able to capture entire sounders. Entire sounder control techniques may cause greater reductions in damage and greater disease control.

Drop-nets were manned and remotely triggered during my study. I was able to wait for the best opportunity to capture every individual before triggering the system to drop. If every hog did not enter the drop-net, I could opt out of dropping it and wait for another opportunity. In this study, use of a man-activated trigger with the drop-net eliminated guesswork and effectively increased capture quantity. Average capture rate for successful trapping events was 10.7 and 3.8 in drop-nets and corral traps, respectively. Similar success in corral traps was achieved by Mersinger and Silvy (2007) with 4.2 individuals per catch event.

Drop-nets were used as a means of mass deer capture in areas of high density (Ramsey, 1968). In my study, mass pig capture was achieved with drop-nets. The ability to capture entire sounders or large groups consistently with drop-nets led to greater effectiveness in my study. Entire sounders were often captured in 1drop and many drop-net captures occurred on the same day in which it was set up. Once habituated to bait, wild pigs would generally run under the net in one clustered group. Occasionally, stragglers stopped to root nearby and walked under the net a few minutes later. The usefulness of a man-activated trigger was realized in these instances.

**Demographics**

Juveniles accounted for a high proportion of overall captures during my study. This is consistent with other studies (McCann and Garcelon 2008, Hanson et al. 2009). Drop-nets caught a higher percentage of males than did corral traps. Research consistently shows boars having lower catch rates than sows and piglets in conventional traps (Choquenot et al. 1993, Williams 2011). Adult boars may be less nutritionally stressed than nursing or pregnant females, (since all adult females are generally nursing or pregnant) leading to a slower or more timid approach to traps or bait. Choquenot et al. (1993) suggested boars have greater survival rates indicating a larger proportion of sows are susceptible to bait consumption than are boars. Drop-nets are less visually intrusive to animals on the ground. There are no confined entry or exit points and no paneling or fencing at ground level. Boars may enter drop-nets more readily than corral traps because they lack vertical structure at ground level. Removing female pigs generally has greater impact on future population size (Hanson et al 2009); however, in some instances, such as a disease outbreak, targeting all pigs including males may be critical. Adult boars have been shown to range over greater distances than do sows, suggesting boars could potentially spread disease over a wider area (McIlroy et al. 1989).

**Non-target Captures**

Animal activated trapping systems are often subject to non-target captures (Campbell and Long 2008, Sumrall 2011). In addition to non-target captures, traps may be triggered by other species that are not captured. Capture or interference from non-target species can limit efficacy of animal activated traps. Certain baits attract multiple species. For instance corn may attract raccoons, opossums (*Didelphis virginiana*), birds, deer, livestock, and small rodents (Campbell and Long 2008, Sumrall 2011). Attempts to determine pig-specific attractants have yielded no pig-specific bait (Campbell and

Long 2008, Sumrall 2011), but suggest species specific repellants may have application for reducing non-target capture (Sumrall 2011). Once a trap has been triggered, it is unlikely wild pigs will manually enter through a closed gate. Therefore, non-target animals springing gates prevent capture of wild pigs. In my study, I caught white-tailed deer and cattle, and observed numerous occurrences where white-tailed deer, cattle, raccoons, or birds bumped the traps, activated the trigger, or landed on the trip wire and fled closed traps. Animal activated trapping systems need to be modified to be species specific for greater efficacy. In my study, man activated triggers (such as used in drop-netting) were effective at eliminating interference from non-target species. Accidental activations and non-target captures are restricted to operator error. When using drop-nets to capture wild pigs in my study, non-target species were avoided, never captured, and never aided in false triggers.

**Trap Wariness**

Diong (1980) documented trap wariness in conventional trapping systems. Trappers, landowners, and managers struggle with the possibility of wild pigs becoming wary of their traps. Population control at a ranch-wide scale is hindered by ineffective trapping methods, unpredictability of pigs, and trap flaws. For example, wild pigs may not enter corral traps because of the confinement, obstruction of view, noise, or reaction from a previous interaction with the same or another trap. Additionally, box or corral traps with trip wires may be triggered before entire sounders have time to enter. The observed noise and panic associated with trapping events in corral traps may cause pigs that are outside a trap when the gate is tripped to be frightened and permanently or temporarily vacate the site. These pigs may learn from negative experiences with corral traps and may associate future encounters with traps with danger. Pigs often appear hesitant in their initial encounter with corral traps. I observed wild pigs approaching recently erected corral traps and consuming bait only up to the gate. I also observed sounders leaving trap sites after corral traps were erected. In some instances, after a partial sounder was captured, pigs were not documented returning to the corral trap for the remainder of the trapping season. In other cases, however, a portion of a sounder was captured in a corral trap, and pigs that were missed from that sounder returned to be captured in the same trap later. This suggests that some traps are capable of subsequent capture or some pigs are susceptible to subsequent trapping events. After a partial sounder is captured with a corral trap, inconsistent capture in subsequent trapping attempts suggests large time investment per site is not efficient. When sounders were captured, juvenile pigs more often entered corral traps before sows. Juvenile pigs appear to be more comfortable with corral traps, especially immediately following trap construction.

When trapping with drop-nets, it is important to be patient and wait until entire sounders are under nets before triggering, as the noise and panic from these events may also reduce subsequent trapping success. Wild pigs did not seem to exhibit the same timid behavior as observed at corral traps and did not appear to associate the overhead net with danger. Wild pigs normally entered drop-nets within the first day of setup without hesitation. Monitoring cameras often detected entire sounders consuming bait in the first triggered picture after drop-net setup (Fig. 6), suggesting these sounders had no reservation about walking under the nets. Additional photographic data of behaviors under the net include pigs lying down and sows nursing young (Fig. 6). On several occasions, pigs returned to drop-net sites and remained under nets for up to 40 min after all corn had been consumed in a previous visit.

Trap area may have affected capture quantity. Use of larger corral traps resulted in larger traps consistently trapping more pigs in less time (Williams et al. 2011). Drop-nets were 335 $m^2$ while corral traps were only 24 $m^2$. Corral traps half this size are common in my study area. I constructed two compartments ($12m^2$) with a common rear panel to give pigs that were not captured in the initial closure a chance to enter the other compartment and be trapped separately. Wild pigs regularly bunched up on bait piles, so my corral compartment area should not have influenced capture quantity, but I attempted to eliminate the possibility by providing a second enclosure with its own bait pile. When corral traps were tripped, most uncaptured pigs vacated the site. When captures occurred in both compartments of one corral trap, they occurred within a couple of minutes of each other. I never caught >6 pigs in both compartments of the same corral trap in one night, but caught as many as 14 in a single compartment. This suggests that maximum corral trap capacity was not reached. Large groups of pigs probably did not enter corral traps because pigs were trap shy or traps were prematurely tripped by the pigs first to enter.

Figure 6. Wild pigs accustomed to drop-net shortly after setup on the Oswalt Road Ranch, Love County, Oklahoma, USA, 2010.

**Subsequent Capture and Escapes**

Many gate or trap designs are conceived with the idea that wild pigs will be able to push gates open and enter the trap after the initial closure (Taylor 1991). Products are often marketed by highlighting these claims. I used doors designed to facilitate "closed door entry" and pigs were given several days to become familiarized with trap gates before trapping. In my 2-year study, I documented no instances of pigs entering closed traps. Capture rate was not different between gate styles. My saloon and single spring gates were the same width. Width of entrance may be what is limiting pig acceptance to the traps rather than gate style. Wider gates may increase trapping success (Williams et al. 2011). I documented subsequent captures with drop-nets and corral traps. Though drop-nets were more effective at removing the identifiable pig population with initial and subsequent capture events, corral traps were still capable of subsequent capture. Traps were only moved when pig presence ceased. Restarting the trapping process by pre-baiting, monitoring with cameras, and moving traps short distances before pigs vacate trap sites may affect subsequent capture effectiveness. Placing bait short distances from traps may decrease wild pigs' anxiety about traps or previous trapping events. Subsequent trapping of these re-conditioned pigs may lead to greater success than subsequent trapping at stationary traps.

Decreased trapping effectiveness in year 2 may have been influenced by trap wary pigs that were missed in year 1 of trapping or abundant native forage availability at the time of trapping. However, increased efficiency in year 2 suggests that more pigs were caught per unit of time. Therefore, decreased effectiveness but increased efficiency in year 2 could have been attributable to overall larger sounder size and more escaped pigs. In year 2, very large sounders were observed in the camera surveys. When trapping large sounders of 30 or more pigs, it is inevitable that some are going to avoid or escape drop-nets and corral traps. They physically cannot all fit into the corral traps and with >10 large pigs in the drop-nets; the probability of an escape is increased. Several adult pigs trapped in a drop-net together have been able to drag the net up to 20 m before becoming entangled. In these instances, pigs moving in the opposite direction of the net have an opportunity to escape. Some individuals within large sounders also start out closer to the edges of the net because of overcrowding around the bait. When a large volume of pigs were under the net, they took longer to settle, were more aggressive with one another, and position under the net was more difficult to evaluate. Small groups of pigs generally allowed all individuals to easily access the bait, form tighter congregations, and provide easy evaluation of location under the net, which resulted in less escape opportunity.

Escapes were a part of both trapping systems. Pigs that escaped from corral traps were either very small (<4.5 kg) and could fit through mesh in the panels, or adults that jumped or climbed over the 1.5-m panels. A popular escape route was over the gate as the trap funneled down to this point. Pigs that escaped from drop-nets were either very small (<4.5 kg) and fit through 10-cm mesh, or escaped during captures when several large pigs pulled the net in opposite directions (Fig. 7). This created resistance for some pigs to crawl out from under the net without becoming entangled.


Figure 7: Large sounder of wild pigs under a drop-net on the Coffey Ranch, Love County, Oklahoma, USA, 2011.

**Efficiency**

I demonstrated a 77% greater effectiveness with a 14% reduction in effort to capture wild pigs with drop-nets when compared to corral traps. Capturing entire sounders or large groups in drop-nets, with the same or less effort than capturing a few hogs in corral traps, led to the greater effectiveness and efficiency in the drop-net system. Increased efficiency in year 2 was probably due to larger sounders using trap sites. Traps also were able to be moved or discontinued sooner after initial setup in year 2 because of less residual use. Removal of 222 pigs in year 1 likely led to fewer sounders and less competition for bait in year 2. Many of the pigs observed in year 2 were likely the result of immigration from adjacent properties. One of the hurdles to long-term reduction of wild pigs is reinvasion into recently controlled areas (Choquenot et al. 1996). In year 1, I observed multiple sounders using a single trap sites; whereas in year 2, many trap sites were used by single sounders. Subsequent captures at a trap site may progressively become less efficient. Time of year also may influence trap efficiency (Stevens 1996). Wild pigs may have turned to other food sources in spring months that were not available when trapping began in January, resulting in less efficient traps. In 2010, I conducted 51 net and 77 corral trapping events. In 2011, I conducted only 19 net and 13 corral trapping events. Identifiable pig estimates suggest fewer total pigs but larger average group sizes were available to capture in year 2. Fewer sounders may have increased my ability to pattern pigs due to less competition with other groups for bait; resulting in more efficient control. In addition, multiple sounder use of a single trap may cause extended (less efficient) trapping periods because of trap area disturbance from prior trapping events.

Drop-nets had a shorter set-up time because of tedious cutting and tying wire on corral traps. Drop-nets required extra construction and maintenance time for electronics maintenance (e.g., changing batteries). I minimized trap observation time by incorporating an infrared-triggered trail camera in the drop-net system. I reviewed the 3 prior days of pig activity at the bait site and determined a time the pigs would likely arrive. I generally arrived at the trap site 1 hr before the expected arrival of the pigs. If a pattern was evident in trail camera photos, drop-nets could be trapped with little time investment. In some instances, pigs displayed no consistent pattern, requiring me to sit in the field for extended periods. This time spent in the field drastically decreased overall efficiency for drop-nets, but still did not make drop-nets less efficient than corral traps.

I observed a higher cost per captured pig in the drop-net system; however, drop-nets were more mobile than corral traps. On large properties, multiple corral traps may be necessary to implement control efforts ranch-wide because of limited mobility and trap ineffectiveness. If one trap is designated for an entire ranch, corral trap ineffectiveness may allow populations to return to previous levels before traps can return to previously trapped areas. Drop-nets caught more pigs in less time, allowing more frequent relocation. One drop-net may provide control over a larger area than corral traps, thus reducing the number of traps necessary per landowner or association of landowners.

# CHAPTER III

# DAMAGE ASSESSMENT

## INTRODUCTION

Since their introduction into the United States, wild pigs (*Sus scrofa*) have caused a variety of ecological and economical damages. When populations encroach on lands managed for livestock or crops, concerns about rooting, trampling, livestock predation, disease transmission, damage to farm equipment, and contamination of water sources are frequent (Peine and Farmer 1990; Choquenot et al. 1996; Taft 1999; Engeman et al. 2004, 2006, 2007; McCann and Garcelon 2008). The long-term damage wild pigs can cause in natural ecosystems also is well documented (Campbell and Long 2009). Damage from rooting behavior includes, but is not limited to, reduction of herbaceous and belowground forages (Howe et al. 1981), destruction of small mammal habitat (Singer et al. 1984, Focardi et al. 2000), introduction of exotic plant species (McCann and Garcelon 2008, Campbell and Long 2009), competition with native wildlife (Stevens 1996, McCann and Garcelon 2008), rubbing on or consuming young saplings (Campbell and Long 2009), and alteration of soil chemistry (Stevens 1996, McCann and Garcelon 2008, Campbell and Long 2009). Many of these alterations can directly or indirectly affect fragile or disappearing ecosystems or endangered species. Vanschoenwinkel et al. (2011) documented plant dispersal by mud wallowing mammals. Wild pigs carry around mud from recent wallows which may promote spread of invasive plants by seed dispersal.

Studies have determined economic losses to wild pigs worldwide and under varying land management situations (Rollins 1993, Pimentel et al. 2002, Engeman et al. 2007). With largest economic losses being reported in agricultural cropland, 1pig may cause approximately $200 in damage each year (Pimentel et al. 2002). Large populations of wild pigs may decimate small agricultural plantings and reduce crop yields to levels that impose economic burden on farmers (Choquenot et al. 1996, Taft 1999). Alternatively, agricultural or hay fields may be rooted enough to cause significant damage to equipment, forcing owners to forego harvest (Stevens 1996). Costs associated with native ecosystems (e.g., repairing fragile ecosystems, protecting endangered species, loss of range utilization, and invasion of rangeland by non-native species) can be difficult to quantify (Engeman et al. 2004, 2006, 2007). Value of damage to native ecosystems has been based on the cost to mitigate the damage or replace lost resources (Engeman et al. 2004), but it is impossible to incorporate values for contingencies such as pigs' impact on state and federally listed endangered species (Engemen et al. 2003). Though it may be difficult to obtain dollar estimates of the damage from wild pigs, damage reductions will certainly reduce costs.

A variety of pig control techniques are implemented in order to mitigate damages (Engeman et al. 2007). Damage abatement strategies vary regionally and seasonally and the search for comprehensive methods is ongoing. Intensive wild pig removal programs have been demonstrated (Choquenot et al. 1993, McCann and Garcelon 2008), but how these programs affect damage occurrence may be of greater value. Damage monitoring can help quantify how much area pigs are impacting and regular assessment may be used to detect fluctuations in pig densities or measure success in control programs. Monitoring damage before and after control is essential as maintenance level control efforts will likely be necessary (Engeman et al. 2007). Engeman et al. (2007) documented instant reductions in damage area with quadrat and line intercept sampling methods after pig removal by hunting. Frequency of occurrence of rooting on randomly selected transects was also used as an index of damage quantity in Australia (Hone 1995).

Techniques to control wild pigs should reduce amount of damage occurring on native rangelands. In my study, I use recurring damage assessment on random transects to determine if extensive wild pig control efforts effectively reduce damage. I hypothesize damage to native rangelands will be reduced over time with implementation of control techniques and drastic reductions will occur after the first season of trapping on study sites in Love County, Oklahoma.

STUDY AREA

This 2-year study was conducted at the Noble Foundation (NF) Oswalt Road Ranch (ORR), NF Coffey Ranch (CR), and Bill Hoffmann's ranch (HR) in Love County, Oklahoma (Fig. 1). The study sites are in the Cross Timbers and Prairies eco-region, which is characterized by a mixture of wooded areas and openings. Wooded areas in the Cross Timbers and Prairies eco-region are often dominated by various oaks *(Quercus spp.)*, elms *(Ulmus spp.)*, and hickories (*Carya spp.*; Gee et al. 1994). Bottomlands are often dominated by oaks, ashes *(Fraxinus spp.)*, elms, hackberries *(Celtis spp.)*, and osage orange (*Maclura pomifera*; Gee et al. 1994). Open areas typical of the Cross Timbers and Prairies eco-region often include grasses such as bluestems *(Andropogon spp.)*, switch grass *(Panicum virgatum)*, and Indian grass *(Sorghastrum nutans)*, as well as numerous forbs (Gee et al. 1994). Very shallow upland sites with limestone bedrock were common on ORR. These sites were dominated by gramas *(Bouteloua spp.)*, bluestems, dropseeds *(Sporobolus spp.)*, and Texas wintergrass *(Stipa leucotricia).* Shallow upland sites had a plethora of annual and perennial forbs associated with them as well. Invasive species including old world bluestem (*Bothriochloa ischaemum*), jointed goatgrass (*Aegilopis cylindrica*), and bromes (*Bromus spp.*) were abundant across ORR. CR was comprised of native rangeland and some tamed pasture with species including bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halapense*). Sandstone hills with exposed rock were common on HR. Greenbriar (*Smilax bona-nox*) was abundant across HR.

The Samuel Roberts Noble Foundation (NF) has owned and managed CR since 1987. Wild pigs were first observed on the ranch in the mid 1990's. In 2000, NF took ownership of ORR. Bill Hoffmann owns HR. It is unknown when pigs were first observed on ORR or HR. Past wild pig management included drop-nets and corral traps on ORR, corral traps on CR, and shooting on HR. All hunting and trapping of wild pigs was prohibited during 1 calendar year prior to my study. Total area of the 3 ranches was approximately 4047 ha.

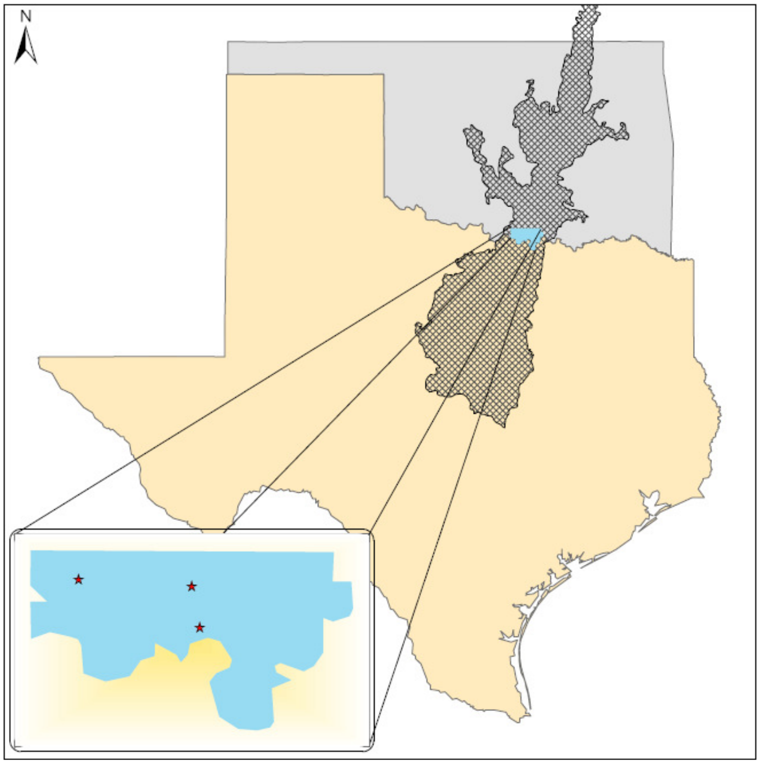


Figure 8: Study sites (stars) in Love County (inset) within the Cross Timbers (shaded) ecoregion stretching from Oklahoma to Texas, 2010.

METHODS

**Transect Sampling**

Various sampling techniques have been used to measure damage in natural ecosystems (Hone 1995, Engeman et al 2007). In my study, I offer an index of damage from area estimates on random transects. Wild pig damage assessments occurred biannually on each of the 3 ranches in the study area. One hundred m transects were identified on ORR (n=92), CR (n=30), and HR (n=30) in Love County. Sampling months varied between ranches, but each ranch was sampled in the same calendar months each year. ORR was sampled in May and September. CR was sampled in June and December. HR was sampled in March and June. I was only interested in illustrating damage changes by ranch over time, so time of year that sampling occurred was not important between ranches.

Transects were fixed throughout my study. They were marked with GPS waypoints and each had specific directional bearings associated with them. Sampling points were at 20, 40, 60, 80, and 100 m along each transect. Damage was measured within a 10-m radius using the point center quarter method (Cottam and Curtis 1956). The nearest hog rooting in each quadrant, if present, was classified as new (soil overturned since most recent rain) or old (crusted over from past rains or re-vegetated), and distance from transect sampling point was measured. If pig rooting occurred directly on a transect sampling point (e.g., at 20 m), all 4 distances were recorded as 1 cm. These distances allowed me to find old damage and document how much healing or re-vegetation occurred since the previous sampling period. An estimate of area impacted by wild pig rooting was measured in each quadrant using rectangular 0.18-$m^2$ quadrats. Surface area of exposed soil from rooting, rounded to the nearest 0.18- $m^2$ was recorded. Quadrats were used as the measuring increment. Damage less than 0.18 $m^2$ was recorded as 1 quadrat worth of damage. Other sign such as scat, tracks, tree rubs, and hair observed in each quarter was recorded if present. In my study healed rooting was defined as new vegetation or thatch that has partially re-vegetated old damage. If obvious healing occurred since the last sampling period, an estimated percent recovery was recorded. Total area impacted on random transects throughout the different treatment areas was monitored and seasonal changes and plant recovery was documented.

**Trapping**

The ORR, CR, and HR were divided into a total of 6 units. Treatments were randomly assigned to the 6 units resulting in 2 units being trapped with corral traps, 2 with drop-nets, and 2 units served as no harvest controls. ORR was trapped with corral traps in the east unit and drop-nets in the west unit. CR was trapped with drop-nets in the east unit and served as a no harvest control in the west unit. HR was trapped with corral traps in the east unit and served as a no harvest control in the west unit. Treatments remained the same in year 2. Trapping was conducted in January - April when natural forage was least available.

Corral traps consisted of 2 adjoining compartments with 2 different gate openings facing opposite one another. These traps were capable of capturing additional pigs in the adjacent compartment once one half was already tripped. Corral traps were constructed with t-posts (1.8 m) and 4.9 m cattle panels with mesh size 10 cm by 10 cm. Panels were 1.5 m in height. Each compartment consisted of 2(4.9 m) panels and a randomly assigned gate type; saloon style or single spring. Each trap incorporated both gate types to examine any differences in pig response. Each gate had solid metal plate welded from 0-30 cm height to allow pigs to enter by pushing open gates in the closed position. The 2 compartments shared a 2.4 m rear panel. The 4.9 m side panels necked down from the rear panel to the width of the door. T-posts were driven into the ground every 1.5 m around the trap and panels were securely fastened to them at every 20 cm in height with medium gauge soft metal wire.

I used the drop-net system described by Gee et al. (1999) for drop-net applications and incorporated an 18.3 X 18.3 m net. The drop-net required human presence to trap. The system incorporates multiple rope harnesses, a release mechanism, solenoids, batteries, and a line-of-sight remote control to trigger the net to drop. I used a Trailmaster active infrared trail monitor (TM 1050, Goodson & Associates, Inc., Lenexa KS, USA) in combination with a radio frequency transmitter and 2-way radio to monitor activity under nets; thereby eliminating the need for constant observation. The drop-net system also was equipped with a remote controlled infrared-filtered spotlight which facilitated nighttime use.

Trap sites were not pre-determined. They were identified where wild pig presence was documented. Multiple sites within each treatment were trapped simultaneously. Once a trap site was determined, the site was pre-baited for 7 days, and if ≥1 pig was patterned (consumed bait in ≥ 3 consecutive days) via camera monitoring during the pre-bait period, a trap was set up. Still and video cameras (Cuddeback NoFlash, Non Typical, Inc., Green Bay, WI, USA) were set up on all trap sites to facilitate individual pig identification, determine identifiable pig population estimates, document pigs' responses to trapping events, monitor residual pig activity at the traps, and assess need for trap relocation. Whole kernel corn was used to bait all traps. Bait (16 kg) was replaced daily as needed.

Trap site pre-baiting occurred for both trap type treatments. Before traps were set up, approximately 16 kg of corn was placed in 1 pile at each trap site. At first, corral trap gates were tied open (3 days minimum) to allow pigs to become familiar with the trap. I poured a line of corn from outside of the corral traps, through the gates, and towards the back of the traps. When pigs consumed the bait and photos documented pig presence inside the corral trap, 16 kg of corn was placed only in the rear half of the corral trap compartments. A horizontal trip wire (2 mm braided cable) was stretched across each compartment 40 cm from the rear at 30 cm height. The trip wire was routed through a 2.5 cm pulley and connected to a prop stick holding the gates open. Corral traps were baited every day, pigs removed, and traps reset until monitoring cameras showed no further pig activity. Corral traps were abandoned and relocated once 5 consecutive no catch days had occurred. Corral traps were relocated until monitoring cameras detected no additional pigs in the treatment unit.

After set-up, drop-nets were baited only around the center pole. Approximately 16kg of corn was placed in 4 or 5 small piles surrounding, but less than 1-m away from, the center pole. While trapping wild pigs with drop-nets, the lowest point in the net or sag between the corner poles, was kept $\geq$ 1.2 m. Dropping from this height did not allow pigs space to escape falling nets and did not interfere with pig movement into the trapping area. Drop-nets could be trapped the night in which they were set up. Subsequent trapping of previously triggered drop-nets occurred if pig visitation was documented for 3 consecutive days. Drop-nets were observed when pigs were patterned, manually dropped, baited daily, and reset when dropped until monitoring cameras showed no further pig activity. Since a camera is part of the drop-net system, net sites were abandoned and relocated once 5 consecutive "no pig picture" days had occurred.

All trapping efforts concluded before 30 April or when no more pigs were being observed at sites throughout the individual treatment areas. Wild pigs were euthanized by brain shot while in the traps using a .22 caliber rifle with full cap ammunition. No other pig harvest or removal was allowed on the study areas.

**Statistical Analysis**

Damage assessments were analyzed using generalized linear models with repeated measures or random effects in SAS® 9.2 (SAS Institute, Inc., Cary, NC). I analyzed the data using 2 response variables. First, I used the total amount of quadrats with damage (total number, or count) to assess the amount of area affected by pigs. Next, I created a new response variable to estimate the probability of encountering damage along a transect; the new variable was a binomial response variable (1 = damage, 0 = no damage). Using the generalized linear model procedure in SAS (PROC GENMOD), I first tested for the effects of ranch ($n = 3$), treatment (1 = treated, 0 = untreated/control pasture), and a time trend variable (analyzed as a continuous covariate) that represented pre-trapping (period = 1), trapping (periods = 2–4), and post-trapping (period = 5) efforts, and all possible interactions. I used these results to reduce model complexity by entering only significant variables into subsequent models. Next, I used generalized estimating equations (GEE) to examine the relationship between the amount of damage (response variable) and the time trend variable. I used a repeated measures design with ‘ranch’ as the subject to specify the unit within which correlation occurs; independence is assumed across ranches (Littell et al. 2006). I specified a negative binomial distribution and log-link function. I also used GEEs to examine the relationship between damage and time period for each individual ranch. Next, I used a generalized linear mixed model (PROC GLIMMIX in SAS) to analyze the probability of encountering damage along each transect as a function of time. I used a binomial distribution (damage = 1, no damage = 0) and a logit link function. Ranch was specified as the random effect in the full model, and then a binomial model was fit for each ranch separately. Area damaged, sum of quads damaged, and probability of encountering damage were plotted over time by ranch. I also used sum of quads on recurring transect sampling to determine damage reduction percentages over time.

RESULTS

After trapping was initiated in spring 2010 on 3 properties in Love County, Oklahoma, USA, wild pig damage decreased over time (Figs. 9 and 10). A test of transect samples ($n$ = 593) showed a significant decrease in damage over time (Z-score = -6.93, $P < 0.001$). I found that time period ($\chi^2 = 28.24$, $df = 1$, $P < 0.001$) and ranch ($\chi^2 = 14.19$, $df = 2$, $P < 0.001$) were significant; all other variables and interactions were nonsignificant ($P \geq 0.440$). Ranches analyzed individually showed significant decreases in damage over time (CR: $\chi^2 = 43.87$, $df = 1$, $P < 0.001$; HR: $\chi^2 = 4.24$, $df = 1$, $P = 0.039$; ORR: $\chi^2 = 12.62$, $df = 1$, $P < 0.001$). Damage decreased by 82, 43, and 79 % from pre-trapping (period 1) to initial year of trapping (period 2) on CR, HR, and ORR, respectively. Damage throughout my study was effectively reduced by 90% on all ranches combined. On 2 of the 3 ranches, no harvest controls restricted harvest to half of the ranch. Even though trapping did not occur in controls, damage was reduced there as well. At HR, corral traps were implemented next to a control. I still documented a reduction in damage at HR suggesting conventional trapping techniques also will have an impact on reducing damage.

In the full model, with ranch specified as a random effect, I found the probability of encountering damage decreased over time (-0.468 ± 0.076; $F_{1,\,589} = 37.97$, $P < 0.001$) (Fig. 10). I also found that probability of encountering damage decreased over time on Coffey (-0.543 ± 0.134; $F_{1,\,147} = 16.43$, $P < 0.001$), Hoffman (-0.262 ± 0.151; $F_{1,\,148} = 3.01$, $P = 0.085$), and Oswalt (-0.535 ± 0.119; $F_{1,\,292} = 20.13$, $P < 0.001$) (Fig. 10).

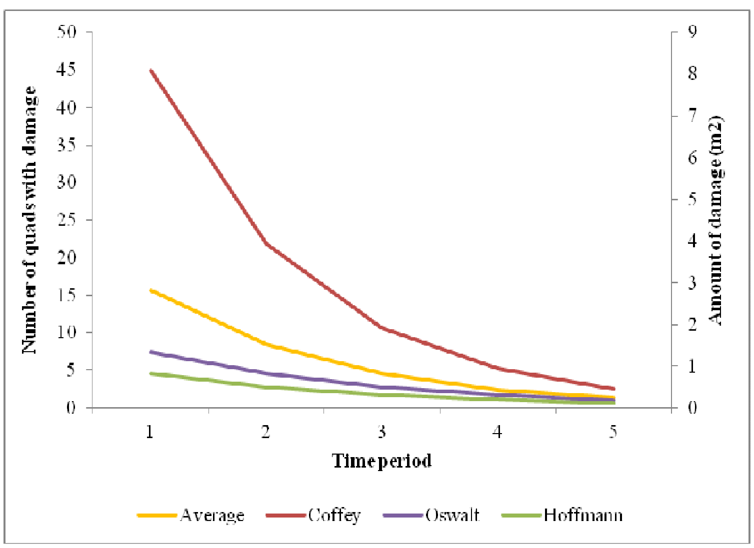


Figure 9: Amount of damage (in sum of quads and m$^2$) on transects (PCQ method) over sampling periods (1–5) for Coffey, Oswalt, and Hoffman Ranches, Love County, Oklahoma, USA for 2009–2012.

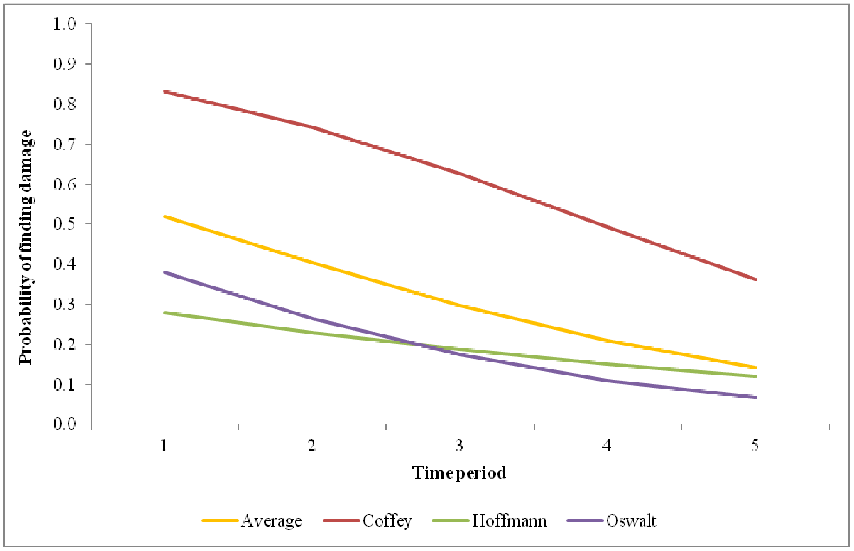


Figure 10: Probability of finding damage on transects (PCQ method) over sampling periods (1–5) for Coffey, Oswalt, and Hoffman Ranches, Love County, Oklahoma, USA for 2009–2012.

## DISCUSSION

Results of my study demonstrated that removal of wild pigs (n=356) from the study area reduced the amount of damage to native rangelands. This was consistent with Geisser and Reyer's (2004) findings in Switzerland and others (Choquenot et al. 1993, Engeman et al. 2007, McCann and Garcelon 2008). After 1 season of trapping, overall damage observed on transects in my study area was reduced by 68%. Damage throughout my study was effectively reduced by 90%. Damage on my study area healed quickly. Cool season annual grasses including jointed goatgrass (*Aegilops cylindrica*), and Japanese brome (*Bromus japonica*) quickly re-vegetated the disturbed soil and was often unnoticed in the next sampling period. These species are non-native and invasive, but are already abundant in the study area. Soil and vegetation type may affect recovery rates. In my study, rooting that occurred on very shallow sites healed at a slower rate than sites characterized by deep soils. Wild pigs generally preferred deeper, moister soils for their rooting activity (Stevens 1996). Most of the damage occurred on loamy bottomland, loamy prairie, or breaks ecological sites on my study area. These ecological sites are either hardwood bottomlands, areas directly adjacent to those bottomlands containing a mixture of grass and shrubs, or steep slopes. Breaks sites likely experience damage from wild pigs because of moisture seeping through fractured rock. Sloped sites may be susceptible to erosion if damage persists. Damage assessments may be used to predict habitat types in which damage will occur on other rangelands and increase efficiency in control programs.

In my study, sounder movements became predictable. Availability of bait patterned pig movements between 2 or 3 bait sites (evident in camera monitoring), allowing localized heavy damage to occur in those areas. In some areas of localized heavy damage, large groups or entire sounders were removed with drop-nets. Visual inspection of data on transects experiencing localized heavy damage and adjacent to trap sites (n=3), show drastic reductions in damaged area after sounders were removed. In my study area, drop-nets were more effective than corral traps at capturing large groups or entire sounders. Capturing large groups or entire sounders should allow localized heavy damage to heal more quickly because a higher proportion of the pigs causing damage are removed. Damage reductions may occur at a larger scale than the area treated (Engeman et al. 2006). In my study, damage reductions were observed in all treatments, including controls. Damage reductions may have been the result of other factors (i.e. pig emigration, increased natural mortality, environmental conditions, decreased reproduction), so future studies should also assess damage on non-trapped areas large enough to eliminate adjacent trapping impact. Control of wild pigs may reduce damage on areas adjacent to treated areas as baiting may concentrate pigs into tighter ranges in close proximity to bait (Campbell et al. 2012). Baiting away from damaged areas also may give land rest if pigs are able to find the bait. Diversionary feeding has been successful with other species including black bear (*Ursus americanus*; Rogers 2009) and the American burying beetle (*Macrophus Americana*; U. S. Fish and Wildlife Service 2005).

Extreme reductions in damage following the first trapping season, suggest rangelands heal quickly from pig damage when populations are controlled. With effective trapping techniques, wild pig numbers can be reduced, allowing damaged habitat to heal. Over time, trapping efforts reduce amount of damage present and amount of damage occurring (by reducing pig numbers) on native rangelands. Continued monitoring should be an integral part of trapping programs, as controlled populations will likely return (Choquenot et al. 1993). Population fluctuations may be detected with damage assessments and indicate when maintenance level control efforts are necessary.

# CHAPTER IV

# DISEASE

## INTRODUCTION

Wild pigs can carry numerous diseases of importance to commercial livestock producers and human health. As wild pig numbers increase, so does the rate of exposure with infected pigs and potential for disease transmission. Wild pigs can be infected with more than 65 diseases that affect livestock (Cooper et al. 2010). Pathogens of most concern to U.S. livestock producers include brucellosis (*Brucella* spp.) and pseudorabies virus (PRV) (Seward et al. 2004). These pathogens can cause devastating impacts (e.g. decreased production, animal deaths, quarantine) if infections reach commercial livestock operations and result in economic burdens to producers. The National Wildlife Disease Program within the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services routinely screens wild pigs for antibodies to PRV and brucellosis. Currently, these pathogens do not exist in U.S. domestic swine operations (U.S. Department of Agriculture, 2012), but Wyckoff et al. (2009) documented that wild pigs have direct contact with domestic pigs. PRRS was first recognized in North America approximately 23 years ago (Collins et al. 1992). It is now found worldwide and causes considerable economic losses in the swine industry (Benfield et al. 1999). Studies have documented prevalence rates to PRV, brucellosis, and PRRS in Oklahoma and Texas (Saliki et al. 1998, Wyckoff et al. 2009). Pedersen et al. (2012) found a 10% exposure rate to *Brucella* species in 181 wild pigs sampled in Oklahoma from 2009-2010. They also found no difference in likelihood of infection between sexes, but adults were more likely than subadults or juveniles to be exposed to brucellosis. Sumrall (2011) reported similar results between age classes. Higher detection was reported in winter months and prevalence varied across state and county lines (Pedersen et al. 2012). Saliki et al. (1998) collected samples from 120 wild pigs in 13 Oklahoma counties. They found no antibodies against brucellosis or PRV in that study. In light of recent Texas studies reporting considerable antibody prevalence in wild pig populations (Wyckoff et al. 2009, Sumrall 2011), obtaining samples from my study area may reveal antibody prevalence above previous levels. With a new and effective control technique, I captured all or most members of the sounders encountered. Removing entire sounders with high exposure rates may have advantages over partial removal, as wild pigs in close proximity to others may be more susceptible to disease transmission if infected individuals are present.

STUDY AREA

This 2-year study was conducted at the Noble Foundation (NF) Oswalt Road Ranch (ORR), NF Coffey Ranch (CR), and Bill Hoffmann's ranch (HR) in Love County, Oklahoma (Fig. 1). The study sites are in the Cross Timbers and Prairies eco-region, which is characterized by a mixture of wooded areas and openings. Wooded areas in the Cross Timbers and Prairies eco-region are often dominated by various oaks *(Quercus spp.)*, elms *(Ulmus spp.)*, and hickories (*Carya spp.*; Gee et al. 1994). Bottomlands are often dominated by oaks, ashes *(Fraxinus spp.)*, elms, hackberries *(Celtis spp.)*, and osage orange (*Maclura pomifera*; Gee et al. 1994). Open areas typical of the Cross Timbers and Prairies eco-region often include grasses such as bluestems

*(Andropogon spp.)*, switch grass *(Panicum virgatum)*, and Indian grass *(Sorghastrum nutans)*, as well as numerous forbs (Gee et al. 1994). Very shallow upland sites with limestone bedrock were common on ORR. These sites were dominated by gramas *(Bouteloua spp.)*, bluestems, dropseeds *(Sporobolus spp.)*, and Texas wintergrass *(Stipa leucotricia).* Shallow upland sites had a plethora of annual and perennial forbs associated with them as well. Invasive species including old world bluestem (*Bothriochloa ischaemum*), jointed goatgrass (*Aegilopis cylindrica*), and bromes (*Bromus spp.*) were abundant across ORR. CR was comprised of native rangeland and some tamed pasture with species including bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halapense*). Sandstone hills with exposed rock were common on HR. Greenbriar (*Smilax bona-nox*) was abundant across HR.

The Samuel Roberts Noble Foundation (NF) has owned and managed CR since 1987. Wild pigs were first observed on the ranch in the mid 1990's. In 2000, NF took ownership of ORR. Bill Hoffmann owns HR. It is unknown when pigs were first observed on ORR or HR. Past wild pig management included drop-nets and corral traps on ORR, corral traps on CR, and shooting on HR. All hunting and trapping of wild pigs was prohibited during 1 calendar year prior to my study. Total area of the 3 ranches was approximately 4047 ha.

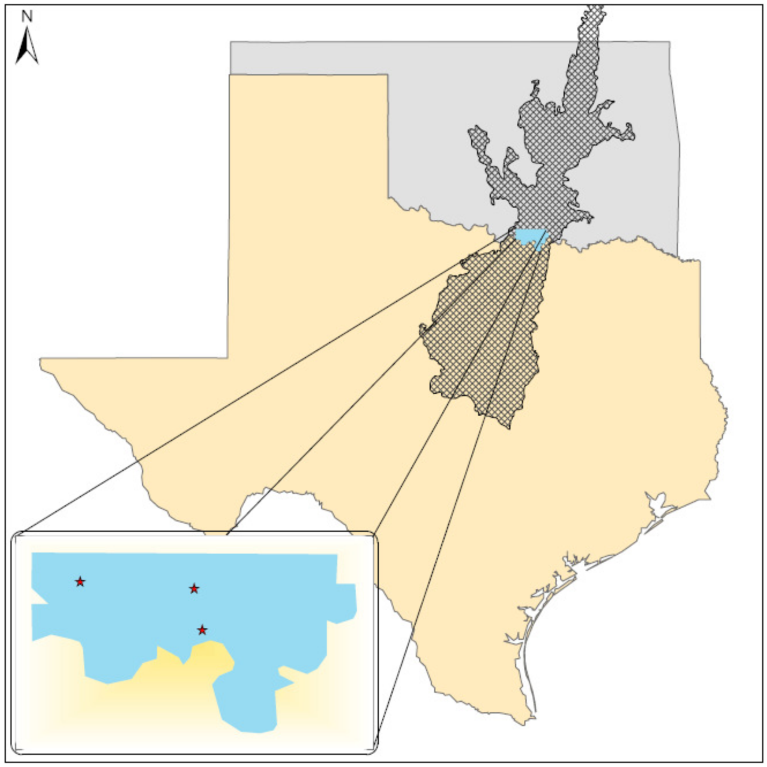


Figure 11: Study sites (stars) in Love County (inset) within the Cross Timbers (shaded) ecoregion stretching from Oklahoma to Texas, 2010.

METHODS

**Trapping**

The ORR, CR, and HR were divided into a total of 6 units. Treatments were randomly assigned to the 6 units resulting in 2 units being trapped with corral traps, 2 with drop-nets, and 2 units served as no harvest controls. ORR was trapped with corral traps in the east unit and drop-nets in the west unit. CR was trapped with drop-nets in the east unit and served as a no harvest control in the west unit. HR was trapped with corral traps in the east unit and served as a no trapping control in the west unit. Treatments remained the same in year 2. Trapping was conducted in January - April when natural forage was less available.

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Trap sites were not pre-determined. They were identified where wild pig presence was documented. Multiple sites within each treatment were trapped simultaneously. Once a trap site was determined, the site was pre-baited for 7 days, and if ≥1 pig was patterned (consumed bait in ≥ 3 consecutive days) during the pre-bait period, a trap was set up. Still and video cameras (Cuddeback NoFlash, Non Typical, Inc., Green Bay, WI, USA) were set up on all trap sites to facilitate individual pig identification, determine identifiable pig population estimates, document pigs' responses to trapping events, monitor residual pig activity at the traps, and assess need for trap relocation. Whole kernel corn was used to bait all traps. Bait (16 kg) was replaced daily as needed.

Trap site pre-baiting occurred for both trap type treatments. Before traps were set up, approximately 16 kg of corn was placed in 1 pile at each trap site. At first, corral trap gates were tied open (3 days minimum) to allow pigs to become familiar with the trap. I poured a line of corn from outside of the corral traps, through the gates, and towards the back of the traps. When pigs consumed the bait and photos documented pig presence inside the corral trap, 16 kg of corn was placed only in the rear half of the corral trap compartments. A horizontal trip wire (2 mm braided cable) was stretched across each compartment 40 cm from the rear at 30 cm height. The trip wire was routed through a 2.5 cm pulley and connected to a prop stick holding the gates open. Corral traps were baited every day, pigs removed, and traps reset until monitoring cameras showed no further pig activity. Corral traps were abandoned and relocated once 5 consecutive no catch days had occurred. Corral traps were relocated until monitoring cameras detected no additional pigs in the treatment unit.

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All trapping efforts concluded before 30 April or when no more pigs were being observed at sites throughout the individual treatment areas. Wild pigs were euthanized by brain shot while in the traps using a .22 caliber rifle with full cap ammunition. No other pig harvest or removal was allowed on the study areas.

**Serology**

Blood was drawn from every wild pig captured for the duration of my project. I collected >10 ml of whole blood from each pig so that >3 ml of serum could be analyzed. I collected blood from euthanized pigs from the heart with a 16 gauge needle 12.7 cm in length. Whole blood was centrifuged at 1,000 X g for 20 min and serum was separated and stored in a freezer (-10 degrees C) with unique ORRHOG, CRHOG, or HRHOG numbers identifying them. Capture data including sex, weight, location, and sounder size was available to cross reference with these identification numbers.

Serum was tested at the National Animal Disease Center in Ames, Iowa, USA. Serum samples were screened using the *Brucella abortus* plate agglutination (BAPA) obtained from the National Veterinary Services Laboratories (NVSL; Ames, Iowa, USA). If samples were positive by BAPA, they were retested using *Brucella* rivanol precipitation assay (RIV; NVSL, Ames, Iowa, USA). If samples had titers considered positive by RIV, then they were retested using *Brucella abortus* fluorescent polarization assay (FPA) obtained from Diachemix (Milwaukee, Wisconsin, USA). To survey for PRV, serum samples were screened using the PRV-gB ELISA (Idexx Laboratories, Westbrook, Maine, USA). Samples indicating a positive titer for PRV were retested in duplicate using the PRV-g1 ELISA (Idexx Laboratories, Westbrook, Maine, USA). To survey for PRRS, serum samples were screened using the PRRSX3 virus enzyme-linked immunosorbent assay (ELISA; Idexx Laboratories, Westbrook, Maine, USA). If samples indicated a positive titer by ELISA, they were retested twice again using the

PRRSX3 ELISA (Idexx Laboratories, Westbrook, Maine, USA). I determined exposure rates to PRV, brucellosis, and PRRS by ranch.

RESULTS

From 283 serum samples collected from wild pigs during spring 2010 ($n$ = 149) and spring 2011 (n=134) in Love County, Oklahoma, I found an overall exposure rate to PRV of 24%. Using PRV-gB ELISA, 68 samples indicated a positive titer for PRV. Those 68 samples were retested in duplicate using the PRV-g1 ELISA and 65 samples had titers that indicated they were positive for PRV. Exposure rates for brucellosis and PRRS were 0.35%. Two samples were positive by BAPA and were retested using RIV. One sample had titers considered positive by RIV and was retested and considered positive using FPA. One sample indicated a positive titer by PRRSX3 ELISA and was retested twice again using the PRRSX3 ELISA and titers were considered positive. PRV exposure rates by ranch were highly variable (Table 2). Antibodies for PRV were detected in 55% and 8% of pigs sampled on ORR and CR, respectively. No antibodies to PRV were detected at HR. Pigs at ORR were 6.9 times more likely to have antibodies for PRV than pigs at CR.

Table 2: Exposure rates in wild pigs (male and female) for pseudorabies (PRV), brucellosis, and Porcine Reproductive and Respiratory Syndrome (PRRSV) on the Oswalt, Coffey, and Hoffmann Ranches, Love County, OK, USA, 2010 and 2011.

| | | Ranch | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Oswalt | | | Coffey | | | Hoffmann | | |
| | | | Positive | | | Positive | | | Positive | |
| Pathogen | Sex | Sera tested | No. | % | Sera tested | No. | % | Sera tested | No. | % |
| PRV | M | 45 | 24 | 53% | 73 | 5 | 7% | 7 | 0 | 0% |
| | F | 54 | 30 | 56% | 92 | 9 | 10% | 12 | 0 | 0% |
| Brucellosis | M | 45 | 1 | 2% | 73 | 0 | 0% | 7 | 0 | 0% |
| | F | 54 | 1 | 2% | 92 | 0 | 0% | 12 | 0 | 0% |
| PRRSV | M | 45 | 0 | 0% | 73 | 0 | 0% | 7 | 0 | 0% |
| | F | 54 | 0 | 0% | 92 | 1 | 1% | 12 | 0 | 0% |

## DISCUSSION

Serosurvey for 3 viral or bacterial diseases of wild pigs in Love County, Oklahoma only showed PRV to be of significant concern. Other studies find a 20.9% (Sumrall 2011) and 29% (Pirtle et al. 1989) exposure rate in wild pigs, complementing my findings of 24%. Those studies were conducted in east Texas and Georgia, respectively. Saliki et al. (1998) did not detect any occurrence of PRV in the 13 counties in central Oklahoma that were sampled. My findings suggest additional sampling may now yield different results in other parts of Oklahoma. Pedersen et al. (2012) found differences at the county and state level. In my study, differences were detected at the ranch level. Ranch level differences occurred between ORR, CR, and HR, demonstrating county level sampling may not be fine scale enough to monitor disease in the state if adequate and representative samples are not obtained. The difference in exposure rates detected at ORR and CR (55 and 8%, respectively) was unexpected considering the ranches' close proximity to one another. The ranches are separated by 4.95 km and were subject to similar management practices and land ownership for the last couple decades. Time of first infection might have occurred earlier at ORR than CR, resulting in greater exposure (Gresham et al. 2002).

Visual inspection of the data revealed sporadic seropositives to PRV in regards to age category, sounder size, and sex on ORR and CR. My sample size was not sufficient to make any inferences on the effects of these characteristics on disease prevalence, especially since a large proportion of seropositives came from a few capture events with drop nets. This does not suggest larger sounders had higher exposure rates, as large sounders with 0% exposure were captured on the same ranch. Continued documentation of high exposure rates in certain areas of the ranch does suggest regular monitoring may increase efficacy of disease control programs (by focusing effort where needed).

One sounder captured at ORR in 2011, comprised of 4 adult females and 21 juveniles, was found to have a 100% prevalence for antibodies to PRV. These juveniles < 10 kg may be acquiring antibodies as neonates through milk or colostrum from lactating females or as fetuses via transplacental transmission (Bouma et al. 1997, Pomeranz et al. 2005). Infected pigs can become latent carriers of PRV. The inactive virus is carried in the trigeminal ganglia in swine, and can become reactivated after stressors including transport, crowding, or farrowing (Pomeranz et al. 2005). Venereal transmission is also possible in adults, and may be the most important method of spread in wild pigs (Romero et al. 2001).

Conventional trapping techniques may be effective at removing juveniles, but still randomly select a portion of the adults. In sounders with high exposure rates, it may be important to capture every individual to reduce the possibility of transmission to livestock, wildlife, or other wild pigs, as missed individuals may join other sounders. Control strategies should focus on all segments of wild pig populations. Many trapping programs preferentially control females and piglets first, as they are easier to capture. These strategies make a bigger and quicker impact on population size and damage losses, but boars should not be neglected. Adult boars have been shown to range over greater distances than do sows (McIlroy et al. 1989, Stevens 1996), suggesting they could more readily facilitate spread of disease to other wildlife and livestock over a larger area (Fig. 12).

As wild pig populations expand, potential spread of disease into new areas increases. Finding antibodies to diseases absent in previous surveys confirms the need for constant monitoring. Though control may not reduce prevalence of several pathogens, it can reduce the density of positive animals that could come into contact with domestic livestock or food animals.


Figure 12: Wild boar consuming bait in close proximity to cattle on Hoffmann Ranch, Love County, Oklahoma, USA, 2011.

# CHAPTER V

# MANAGEMENT IMPLICATIONS AND SUMMARY

## MANAGEMENT IMPLICATIONS

Capturing large groups or sounders in single drops contribute to more effective and efficient control techniques. Drop-nets have proven effective at removing all or most members of sounders, which has implications for accelerated reductions in wild pig damage and less potential for spread of diseases. Future trapping techniques should focus on inclusion of trap-wary individuals, exclusion of non-target species, and consistent control of entire sounders or very large groups in single trapping events. Trappers often struggle with adult boars being wary of corral traps. Drop-nets were more effective at capturing adult boars. To suppress spread of disease, boars should not be neglected as their ranges are larger than sows and they inherently come into contact with more wildlife and livestock. Successfully removing 70% of the population may be necessary to keep wild pig populations in check. This could be achieved with drop-nets, but may be difficult with conventional corral traps. My research suggests that there may be value in using both of these trapping techniques in an integrated fashion, but further investigation is needed to determine how the techniques complement one another to capture trap informed pigs. Drop-net systems cost approximately $3,500 while corral trap systems described in this study cost approximately $500. Costs of drop-nets may be prohibitive to many landowners and managers, however, associations or groups of landowners and managers may be able to share initial costs and implement the drop net (which is portable) on a larger scale than just the ranch level. Such larger scale reduction in wild pig numbers can reduce costs necessary to mitigate damage and combat disease. Small landholdings alone may not reap the benefits of control efforts. Though drop-nets may seem like they require more labor and effort for control of wild pigs, my study demonstrated they do not. Not only were drop-nets more efficient, but they actually required less time to set up and caught pigs quicker at a site allowing them to be moved to a new location.

**Baiting Methods**

Factors associated with baiting methods that may influence site usage include, but are not limited to, bait placement, time of baiting, bait quantity, bait type, and area disturbance. Additional research is needed to identify proper baiting techniques to optimize catch. Successfully attracting whole sounders of wild pigs to traps may require "going to the pigs," meaning placing bait in areas of concentrated pig activity. Such areas may include riparian areas, heavily used trails to and from water or food sources, or water sources themselves. Available water is likely an attractant and baiting pigs adjacent to these features may increase visitation.

Time that bait is dispensed may need to be consistent from day to day so as not to encounter and/or scare pigs away from bait sites. Trail cameras can be very useful in determining the time pigs arrive at trap sites and provide guidance on bait dispensing During my study, wild pigs were occasionally approached when I arrived to dispense bait. It is unknown how this may affect wild pigs, but efforts to avoid startling pigs at trap sites will likely increase chances of success. Scent deposition also may inhibit success.

Bait quantity may also be important when trying to capture entire sounders in 1 trapping event. Large quantities of bait on the ground may inhibit the initial “rush for the bait” behavior when sounders first approach a trap site. When trapping pigs, I wanted them to race to the bait and consume the entire pile in less than 1 hour. Competition for bait between sounder-mates may increase trapping efficiency and capture rates up to an optimum sounder size. Excess competition may decrease efficacy. Large quantities of bait removes some of the need to compete for bait and may reward pigs that do not consume bait at the onset of the sounder visit; thereby reducing the possibility of capturing the entire sounder. Baiting in excess may reduce trapping success in corral traps and may require trappers using man-activated systems to wait for extended periods of time before triggering a trap.

**Weather**

In colder climates, weather conditions may adversely affect trapping success. As wild pigs ranges expand northward into regions that often see frozen precipitation, another element is added to trapping. Planning around the weather may play an important role in successful trapping. Snow and/or freezing precipitation will affect different trap systems differently. Corral traps gates will not close properly after 2 inches of snow accumulation. In such weather conditions, corral traps should be wired open and re-activated when weather conditions improve and gates are tested. Ice also may accumulate on trip wires, hinges, or props sticks resulting in false or dead triggers. Wiring gates open is easy and eliminates false triggers or moving gates that may contribute to alternative pig behavior on subsequent visits. Pigs escaping through partially closed gates may educate them about corral traps.

Snow and/or freezing precipitation have not prohibit the drop-net system from triggering, however, the weight of the net covered in snow or ice may pull anchors out of the ground or snap center poles. This damage to equipment may cause added expense and/or further delays in trapping. Before such weather conditions, nets should be detached from corner poles and rolled up. Corner poles and all other hardware can stay in place. Nets can be replaced with little effort after weather conditions improve. In conditions where some snow is expected in a short time period, the nets can be shaken periodically to remove accumulated snow, without taking them down.

**Damage**

Intensive wild pig removal accomplished with one or more techniques will likely result in reductions in damage occurring on a variety of landscapes. Continued assessment of damage on landscapes can be used to evaluate the need for additional maintenance level control efforts. Fluctuations in area damaged will likely mimic pig population levels.

**Disease**

Control techniques designed to remove entire sounders or large groups implemented in high prevalence areas will likely have greatest impact on disease reduction. Continued disease monitoring at the ranch level may be advantageous to target areas of greatest concern before seropositive populations expand to uncontrollable levels.

## SUMMARY

My study found drop-nets to be an effective tool for the capture of wild pigs, with high capture efficiency (CPUE), minimal escapes, selective capture (because an operator controls the drop), and ability to remove a large proportion of identified pig populations. Drop-nets warrant inclusion in the assortment of wild pig control techniques and may be a viable alternative or addition to existing control programs with objectives to abate damage and disease.

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